NATIONAL ASSOCIATION

OF

CEMENT USERS

American Concrete Institute

PROCEEDINGS

OF THE

SIXTH ANNUAL CONVENTION

Held at Chicago, Illinois,

February 21, 22, 23, 24, 25, 1910

VOLUME VI

EDITED BY THE PRESIDENT

PUBLISHED BY THE ASSOCIATION
1910

CONTENTS

PLATES.

LIST OF OFFICERS

OF

THE NATIONAL ASSOCIATION OF CEMENT USERS

1910.

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EDWARD D. BOYER.

SECOND VICE-PRESIDENT.

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THIRD VICE-PRESIDENT.

E. S. LARNED.

FOURTH VICE-PRESIDENT.

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ACTING SECRETARY.

EDWARD E. KRAUSS.

TREASURER.

H. C. TURNER.

SECTIONAL VICE-PRESIDENTS.

(See page 7.)

SECTIONAL COMMITTEES

(The Chairmen are Vice-Presidents of the Association.)

BUILDING BLOCKS AND CEMENT PRODUCTS.

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F. W. MOSES,
EMILE G. PERROT,
J. P. H. PERRY.
JULIUS KAHN.

REINFORCED CONCRETE AND BUILDING LAWS.

ALFRED E. LINDAU, *Chairman.*

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ARTHUR N. TALBOT,
SANFORD E. THOMPSON,
H. C. TURNER.

ROADWAYS, SIDEWALKS AND FLOORS.

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A. C. BIRNIE,
W. W. SCHOULER,
A. E. SNODGRASS.

TREATMENT OF CONCRETE SURFACES.

LEONARD C. WASON, *Chairman.*

CLOYD M. CHAPMAN,
ALBERT MOYER,
H. H. QUIMBY,
ERNEST J. RUSSELL.

SPECIAL COMMITTEE.

ON COURSES OF INSTRUCTION.

LOGAN WALLER PAGE, *Chairman.*
PERCY H. WILSON, *Secretary.*
(In course of organization.)

PAST OFFICERS.

President.	1905	John P. Given. (Presiding Officer First Convention.)
	1905–9	Richard L. Humphrey.
First Vice-President.	1905	A. L. Goetzmann.
	1906–9	Merrill Watson.
Second Vice-President.	1905–6	John H. Fellows.
	1907–9	M. S. Daniels.
Third Vice-President.	1905	H. C. Quinn.
	1906–7	O. U. Miracle.
	1908	S. B. Newberry.
	1909	E. S. Larned.
Fourth Vice-President.	1905–7	A. Monsted.
	1908–9	George C. Walters.
Treasurer.	1905	A. S. J. Gammon.
	1906–9	H. C. Turner.
Secretary.	1905–6	Charles C. Brown.
	1907	W. W. Curtis.
	1908–9	George C. Wright.

CHARTER

OF

THE NATIONAL ASSOCIATION OF CEMENT USERS.

KNOW ALL MEN BY THESE PRESENTS, That we, the undersigned, all of whom are citizens of the United States, and a majority of whom are residents of the District of Columbia, have associated ourselves together for the purpose hereinafter set forth and desiring that we may be incorporated as an Association under sub-chapter three (3) of the Incorporation Laws of the District of Columbia, as provided in the Code of Law of the District of Columbia, enacted by Congress and approved by the President of the United States, do hereby certify:

1. Name. The name of the proposed corporation is "The National Association of Cement Users."

2. Term of Existence. The existence of the said corporation shall be perpetual.

3. Objects. The particular business and objects of the said corporation shall be to disseminate information and experience upon and to promote the best methods to be employed in the various uses of cement by means of convention, the reading and discussion of papers upon materials of a cement nature and their uses, by social and friendly intercourse at such conventions, the exhibition and study of materials, machinery and methods and to circulate among its members by means of publications the information thus obtained.

4. Incorporators. The number of its managers for the first year shall be fifteen.

In Witness Whereof, we have hereunto set our hands and seals this fourteenth day of December, A. D. 1906.

RICHARD L. HUMPHREY, (SEAL)
JOHN STEPHEN SEWELL, (SEAL)
S. S. VOORHEES. (SEAL)

OFFICE OF RECORDER OF DEEDS,
DISTRICT OF COLUMBIA.

This is to certify that the foregoing is a true and verified copy of a Certificate of Incorporation, and of the whole of such Certificate as received for record in this office at 9:49 A. M., the 19th day of December, A. D. 1906.

In testimony whereof I have hereunto set my hand and affixed the seal of this office, this 20th day of December, A. D. 1906.

(Signed) R. W. DUTTON,
Deputy Recorder of Deeds,
District of Columbia.

(SEAL)

BY-LAWS

OF

THE NATIONAL ASSOCIATION OF CEMENT USERS.

Article I.

MEMBERS.

Section 1. Any company or persons engaged in the construction or maintenance of work in which cement is used, or qualified by business relations or practical experience to co-operate in the purposes of this Association, or engaged in the manufacture or sale of machinery or supplies for cement users, or a man who has attained eminence in the field of engineering, architecture or applied science, is eligible for membership.

Sec. 2. A company shall be treated as a single member and allowed but one vote.

Sec. 3. Any member contributing annually twenty or more dollars in addition to the regular dues shall be designated and listed as a Contributing Member.

Sec. 4. Application for membership shall be made to the Secretary on a form prescribed by the Executive Board. The Secretary shall submit monthly to each member of the Executive Board for letter ballot a list of all applications for membership on hand at that time with a statement of the qualifications, and a two-thirds majority of the members of the Executive Board shall be necessary to an election.

Sec. 5. Resignations from membership must be presented in writing to the Secretary within thirty days after the close of the fiscal year and shall be acceptable provided the dues are paid for that year.

ARTICLE II.

OFFICERS.

SECTION 1. The officers shall be the President, the Vice-Presidents, the Secretary and the Treasurer, who, together with the five latest living Past-Presidents, shall constitute the Executive Board. Vacancies occurring during the year shall be filled by the Executive Board.

SEC. 2. The Elective Members of the Executive Board consisting of the President, the First, the Second, the Third and the Fourth Vice-Presidents, shall be elected annually by ballot at the convention at a business session fixed by the Executive Board and shall hold office until their successors shall qualify.

SEC. 3. The Elective Members of the Executive Board shall appoint the Secretary and the Treasurer; they shall create such special committees as may be deemed desirable for the purpose of preparing recommended standards concerning the proper use of cement for consideration by the Association, and shall appoint a chairman for each committee who shall be a Vice-President of the Association. Four additional members on each special committee shall be appointed by the President, in consultation with the Chairman.

SEC. 4. It shall be the duty of the Executive Board to audit the accounts of the Secretary and the Treasurer before each annual convention.

SEC. 5. The Executive Board shall appoint a Committee on Nomination of Officers and a Committee on Resolutions, to be announced by the President at the first regular session of the annual convention.

SEC. 6. There shall be an Executive Committee of the Executive Board consisting of the President, the Secretary, the Treasurer and two of its members, appointed by the Executive Board.

SEC. 7. The Executive Committee shall manage the affairs of the Association during the interim between the meetings of the Executive Board.

SEC. 8. The President shall have general supervision of the affairs of the Association. He shall preside at the Annual Con-

vention, at the meetings of the Executive Board and the Executive Committee, and shall be ex-officio member of all committees.

The Vice-Presidents in order of seniority shall discharge the duties of the President in his absence.

Sec. 9. The Secretary shall perform such duties and furnish such bond as may be determined by the Executive Board.

Sec. 10. The Treasurer shall be the custodian of the funds of the Association and shall disburse the same in the manner prescribed by the Executive Board. He shall furnish bond in such sum as the Executive Board may determine.

Sec. 11. The Secretary and the Treasurer shall receive such salaries as may be fixed by the Executive Board.

Article III.

meetings.

Section 1. The Association shall meet annually. The time and place shall be fixed by the Executive Board and notice of this action shall be mailed to all members at least thirty days previous to the date of the Convention.

Sec. 2. The Executive Board shall meet during the Convention at which it was elected, effect organization, and transact such business as may be necessary.

Sec. 3. The Executive Board shall meet at least twice each year. The time and place to be fixed by the Executive Committee.

Article IV.

dues.

Section 1. The fiscal year shall commence on the first of July and all dues shall be payable in advance.

Sec. 2. The annual dues of each member shall be five dollars ($5.00).

Sec. 3. A member whose dues remain unpaid for a period of one year shall forfeit the privilege of membership and shall be officially notified to this effect by the Secretary, and if these dues are not paid within thirty days thereafter his name shall be stricken from the list of members. Members may be reinstated upon the payment of all charges upon the books of the Association.

Article V.

STANDARD SPECIFICATIONS.

Section 1. Proposed Standard Specifications to be submitted to the Association must be mailed to the members at least thirty days prior to the Annual Convention, and as there amended and approved, passed to letter ballot, which shall be canvassed within sixty days thereafter, such specifications shall be considered adopted unless at least ten per cent. of the total membership shall vote in the negative.

Article VI.

AMENDMENT.

Section 1. Amendments to these By-Laws, signed by at least three members, must be presented in writing to the Executive Board prior to November 1st and shall be printed in the notice of the annual convention. These amendments may be discussed and amended at the annual convention and passed to letter ballot by a two-thirds vote of those present. Two-thirds of the votes cast by letter ballot shall be necessary for their adoption.

SUMMARY OF THE PROCEEDINGS OF THE SIXTH ANNUAL CONVENTION.

MONDAY, FEBRUARY 21, 1910, 3.00 P. M.

Meeting of Section on Roadways, Sidewalks and Floors.

President Humphrey in the Chair.

This meeting was devoted to a topical discussion covering the preparation of materials, laying, joints, dusting, etc.

FIRST SESSION—MONDAY, FEBRUARY 21, 1910, 8.00 P. M.

The Convention was called to order by President Richard L. Humphrey.

An address of welcome to the City of Chicago was delivered by George M. Bagby, Assistant Corporation Counsel, on behalf of the Mayor of Chicago, the Honorable Fred A. Busse, as follows:

Mr. President and Honored Guests: I deem it a great privilege and honor to have the opportunity of representing his Honor, the Mayor, on this occasion, and in his name extending a most cordial welcome to business men representing not alone every section of our own great country, but I may say of the world; for I have been advised that there are delegates here who are non-residents of America.

The City of Chicago is annually the scene of conventions representing interests as diversified as those in which human activity is engaged or human effort is employed; but there is none to which this administration is more gratified to extend a welcome, than those representative of the business interests.

Chicago is essentially the product of the activity, alertness, energy and industry of its business men, and to them is justly attributable its wonderful growth and marvelous progress within comparatively recent years. The present administration of the city prides itself upon being a distinctively business administration. It has endeavored to employ the same accepted business methods in the administration of public affairs as those which have secured success in private affairs. The adoption of these methods in the conduct of public business involved a radical change from the methods that formerly obtained—and the many beneficiaries of the latter, together with their friends, have not always viewed the change with

equanimity, or placidity of temper. In some instances, reputable citizens, those whose voice and influence should be always on the side of public good, have not scrupled to criticise, and even denounce, that which they did not fully understand. We invite impartial investigation, feeling confident that when our good people are fully informed their verdict will be favorable to the administration which is being administered with the greatest economy consistent with efficiency, and from whose disbursements the public receives the greatest possible return.

In the past the people of this great city have devoted themselves so exclusively to the material development of themselves and the city, that very little heed has been given the city's beautification. It has been reliably stated that no investment of the municipality of Paris, France, has given such generous returns as the money expended in the city's adornment and embellishment. Its beautification annually attracts travelers from every quarter of the globe. It has made it the Mecca alike of those traveling for pleasure or business. This influx of visitors forms a ceaseless stream, every flowing toward and into the matchless city of the French. Business is thereby given an impetus and commercial activity is the order of every day. It is immune from those periods of business stagnation incident to almost every other city of the world; and this exemption is solely due to the fascination and attraction of its urban beauty.

Chicago has taken counsel of these things and has in contemplation the beautification of this great city. It contemplates the building of a connecting link of boulevards upon the street immediately east of Michigan Avenue, which will perfect a circle of parks and boulevards of the city. It has tentative propositions submitted looking to the subwaying of the downtown, or what is locally known as the "Loop" district, the primary object of which is to relieve the congestion upon the street surface and thus expedite and facilitate the transaction of business. The proper adornment of Grant Park on our immediate east is also engaging our most earnest thought, while a recent special session of the Legislature passed an act providing for an island in Lake Michigan just east of Grant Park as a proper location for the great museum, the munificent gift to Chicago by its great merchant prince, Marshall Field. These are but a very few of the important things Chicago has in view. Into their construction and completion, the commodity in the interest of which you are convened, must of necessity enter very largely; therefore, your meeting here, at this time, is indeed opportune.

And now, on behalf of the City of Chicago, and in the name of its Mayor, I again extend you a most cordial welcome, hoping that your visit here will prove, individually and collectively, beneficial and profitable to you all, and that when you return to your respective homes it will be with pleasant recollections of your sojourn in our midst and with a firm conviction that Chicago has a hospitable citizenship and is the premier convention city of the world.

In response to this welcome, President Humphrey expressed the appreciation of the Association in being able to again convene in the City of Chicago, and commented upon the remarkable advance in the use of concrete in that city.

President Humphrey then introduced Christian C. Kohlsaat, Judge of the United States Circuit Court of the Seventh District and President of the Lewis Institute, who extended a welcome on behalf of the educational institutions of Chicago;

Mr. President and Gentlemen: In assuming to represent the cause of education in connection with the sentiment assigned me, I own up to a consciousness of presumption on my part, since my vocation as a practical educator rests in disposition, rather than in experience.

Something more than twenty years ago, Allen C. Lewis, then a citizen of Chicago, departed this life. By his will, the sum of $550,000 was set apart for the establishment of a polytechnic school. That amount seemed adequate for the purpose of those days; now we could hardly build one wing of such an institution for that sum. The fund was nursed until about twelve years ago, when it had been increased by wise management to the sum of about $1,400,000. Land was then procured and a building erected. That was Lewis Institute. From time to time additional buildings and improvements have been added, until now we have a plant valued at one-half a million dollars; a teaching force of almost a hundred, and an attendance exceeding 2,600 young men and women.

My connection with the financial management of this great school is the only justification I can adduce for my temerity in speaking for education.

Last Saturday evening, in company with my wife, I visited your exposition at the Coliseum. We tramped up and down the aisles, seeking for some extraordinary display of your art. We found a few blocks, some columns, monuments, and other modest constructions—among them the cement sarcophagus, but took on disappointment at the meager display —judged from a lawyer's standpoint. Instead of things of beauty for the eye, we were beset by the bewildering din of the machinery. Then it occurred to me that you had gone beyond the point of showing what you could do. You have reached the point of showing how to do it. You were seeking for and disclosing the means rather than the result. It then became clear to me that you had so far conquered obstacles as to confidently claim that you had an article which could and in time would displace the present and past construction materials. To that proposition I am fully converted. Life's greatest lesson is to learn how to do things. To translate knowledge into works, is the crying demand of present-day education. In this respect, most of our schools have been remiss. Hands should be given to thought. The minds of school children might better be led toward the earth than

toward the clouds. Educationally, doing is the apotheosis of thinking. Men of action like yourselves should, in some way, bring your experience to the aid of those who are teaching.

There are in Lewis Institute something over 1,200 boys and girls who are learning to do things. We deem it the most important part of our work. Recently, we have inaugurated a scheme whereby the boys from the various factories can secure educational privileges. The employers have heartily co-operated with the school. The boys are allowed to spend each alternate week in the school, while their wages are kept up as though they were at the shop. In addition, the employers have paid the required tuition. If school duties are neglected, these wages of the boys are docked. The result has been very satisfactory. One of our prominent and public-spirited citizens has become greatly interested in the plan, Mr. La Verne Noyes, and has offered to pay the tuition of boys who wish to attend school and cannot afford to pay, up to the number of 200. This would require a very large sum of money. Thus, the boys are earning money for the home people, while at the same time they are training their faculties and their hands. What a world of opportunity such a provision affords! It is proposed that the girls, too, shall have their chance to make a practical application of what they are taught. What a helpless lot of housekeepers are sent into the world every year, to care for the wage-earners and their children! It seems appalling that so many women enter upon the wifely duties without any reasonable preparation for the arduous life. No knowledge of hygienic cooking; no skill in managing or sewing or making the best of life. How much of the misery—yes, the mortality of humanity is chargeable to ignorance in the matter of preparing food. The waste cannot be estimated. Surely, the major part of the food people eat is made injurious by the cooking. So we wish the girls to put their knowledge of science to practical cooking, clever sewing, and sane housekeeping. The moral of it all to you men is that you should become or cause to be produced centers of thinking and doing in your several localities. You cannot ignore this duty and be guiltless.

To my mind cement is coming; it is the one thing in building material that is growing beyond every other. It holds out great inducement to capital and skill—business and technical. I doubt if there be any other line of business which will attract and require skilled young men to as great an extent as will yours in the near future. Will you not give this matter your thoughtful attention? Lend your hearty support to every effort looking to the establishment of means for the head and hand education of the young. You will reap a rich harvest. The work is great and demands your best attention.

Like my friend here, I do not feel like letting the occasion go without calling your attention to Chicago. You probably have heard the subject mentioned before. Its betterment and beautification are upon the hearts of many of our citizens. One can hardly fail to note among its defects the character of its buildings. Were one to go up in a balloon and take a

bird's-eye view down upon our streets, he would be reminded of the tooth lines of a five-year-old boy—some vacant places, some stumps, some fangs stabbing the air, and all broken and uneven. Here and there a twenty to twenty-five-story building with a whole village of tenants—a very Tower of Babel, whereby the builders have far outstripped the Babel of old, and have succeeded in laying hold of their god—money. Others have been content to build modestly. What will be the solvent which shall, as with a magic wand reduce this ragged line to symmetry and beauty? I think it will in a large measure be cement. Chicago must one day be beautiful as it will be great. You will, I am sure, do your share.

It is not long ago—one hundred and twenty years ago—there was a great battle fought down near Fort Wayne. Old Mad Anthony Wayne was the man who led the troops in that battle. He was the third one that General Washington had sent out to take care of the Indians. The others with their armies had been annihilated, practically. But Mad Anthony Wayne was not that kind. The old Indian chief said to his braves, "Be careful. Don't attack. This man fights. He never sleeps." But they tried it and he wiped them off the battlefield with such vigor that they were glad to make a compromise—glad to make treaties—glad to surrender. The result of that was, among other things, that a tract of land upon which this building stands, six miles square, at the mouth of the river, was ceded to the United States.

Now it is only one hundred and twenty years ago that we bought this by a bloody victory over the Indians. I have been here long enough to see the old frame buildings and the up-and-down sidewalks give way to level sidewalks and modern buildings, and these give way to the Great Fire, and the Great Fire give way to these palaces. This city has grown—grown wonderfully. And, gentlemen of the cement trade, this city will be your Mecca, because it will demand your services and your products. To my mind there is nothing that will fairly compete with you in building up cities. We hope to see your work carried to its best results right here in Chicago. We will give you a hearty welcome, and if you will help make Chicago look better and be better, we will welcome you every year that you choose to hold a convention here.

The President:

I think Judge Kohlsaat has touched upon one of the vital points of the cement industry when he refers to the necessity of training people to do things properly. In an industry as young as this there could be no more effective help given than to so train the men who actually do the work, that they can do it properly. I had hoped the Judge would say that in the school he has so well described there would be formed a department for the cement user, where one would go and learn how to do work properly.

I feel quite sure that we will sometime come back and see the beau-

tiful city of Chicago, which perhaps some of us may assist to create. I think this gives us a helpful thought for which we are thankful, and I wish to thank Judge Kohlsaat on behalf of the Association for his very interesting address.

There are a great many men in the city of Chicago who have been identified with important works and I want to introduce to you one of these, Mr. John M. Ewen, who is to speak to us on behalf of the engineering and contracting interests.

Mr. John M. Ewen:

Mr. President and Members of the National Association of Cement Users: When I was asked a few weeks ago to address you, I endeavored to ascertain upon what particular phase of concrete construction I was expected to talk, and having failed to receive any suggestion that might help me, I decided on my own initiative to touch upon two phases of the subject, the first one along the line of improvement and invention and the second one along the line of caution.

The first phase upon which I wish to dwell is one that I hope may lead to improvements in methods of construction and perhaps to invention. I speak from practical experience, as I have constructed a number of large concrete buildings. Ten years ago I was employed by one of the largest construction companies of America to make a report to them upon this new method of constructing buildings of concrete that we were all at that time hearing so much about. I found that at that time, as you all are aware, there was very little actual work executed in heavy reinforced concrete construction, so that I was forced to devote myself very largely to theory. I spent several months studying the subject and confess I became somewhat prejudiced against it, though I endeavored to keep an open mind and be fair to all of the interests concerned. I had never, up to that time, had to do with any reinforced concrete structures, so that in order to see what had been done I visited a number of cities of the country not farther west than St. Louis and gathered from all of these sources as much information as I could get. In Chicago, for instance, I found but a few of the important architects and engineers who would talk upon the subject at all and, while they generally approved of concrete construction, each feared to be the first to venture in the actual use of it for large buildings. While I found that the same feeling prevailed in other cities, I also found that the general sentiment was more favorable, for the reason, I believe, that the work was not so heavy, the buildings not so large.

I finally completed my report, embodying in my recommendation that concrete construction had come to stay. I believed in it thoroughly and urged in the strongest manner that the company, to keep abreast of the times, should adopt this method of construction in their building work. This, I am glad to say, was followed out, and to-day this company is doing its share of this class of work.

I have derived during the last few days a great deal of pleasure and benefit in the visits that I have paid to the exposition that is now on here in Chicago, and could not help but be struck by the great strides that have taken place during the past ten years. The character of the exhibits, the character of the machinery and the design of the excellent mixers are all of a higher grade than even of a few years ago. This advance in the art is bound to continue year after year. We are but on the threshold, and I predict that in another ten years we will look back upon the appliances of to-day and wonder that we could ever have used them, much as we look back upon the locomotive of earlier construction and wonder.

I do not believe that the lines upon which we are working in reinforced concrete construction for buildings are along the right direction. We are following the methods peculiar to steel construction too closely. Our monolithic floors are so designed that the strains follow the lines of the reinforced bars exactly as they do in the case of steel construction. A monolith of concrete should act as a monolith of stone. If construction made of concrete could be so reinforced with steel or other material that the strains in the monolith could be made to go in every direction to the bearings, I believe we would have an ideal method of construction for both economy and strength. To illustrate: If we should use a 6-in. steel slab, 20 ft. square, and place it upon four walls, the strains from the load superimposed would travel in every direction to these four walls. The strains would not act as they do in present reinforced work along the direction of the rods to the girders and then through the girders to the columns, but would travel directly in all directions to the bearings. Of course we cannot afford 6-in. steel slabs, and we know if we build concrete slabs of that thickness without reinforcement that they will not hold up. Therefore we place in these concrete slabs reinforcement in the shape of bars, a few inches apart, and carry the loads in the same direction that we do by the use of beams in the ordinary tile construction when if the reinforcing bars were so small, or of the same homogeneous texture as the concrete itself, we would carry the loads to the bearings in every direction. The nearest example that I can think of to illustrate is the introduction of a carpet of finely-meshed metal into the soffits of the slabs either by mechanical means or by electro deposits. At the present time this seems impossible and it may never be worked out, but improvement along the lines of my suggestion I firmly believe will be adopted in the near future. It is difficult to express my suggestions without drawings and illustrations, but I believe that those of you who are actually engaged in this work will understand what I am trying to convey and that work will be done along the lines I have suggested. This will simplify, if not entirely eliminate the very clumsy, expensive system that we now have for centering and for forms.

I do not believe it is necessary for me to emphasize the necessity for care that must be taken to prevent accidents, for I think the art has been so far developed that the chances taken are greatly reduced. But

do not forget that one accident is not only very damaging to the contractor interested, but is very damaging to the entire business.

Touching upon the second phase of my talk to you this afternoon, that of caution, it has been my duty a number of times to examine and make reports upon the business of companies engaged in concrete construction, and especially the business of those engaged in making concrete to imitate stone. The experience that I have obtained in doing this work I hope will be of benefit to those of you who are engaged in the development of the concrete business.

The companies in question became involved in financial difficulties, I believe, for the direct reason that they endeavored to execute architectural exterior work to compete with terra cotta, granite and stone, thereby deliberately setting for themselves a task most difficult to achieve. They made contracts to manufacture and set in place the concrete material in the same manner that a stone contractor would set his materials, and promised that their concrete would be equal to the material with which they were competing. They placed themselves in the position of inviting hypercritical criticism which is, as many of you know, almost fatal in construction work.

The art is new. There has been very little of the work done that is older than ten or fifteen years. The architects are forced into the position where they must be very careful in order to protect the interests of their clients, more careful than they would be if the material that was being used were stone or granite. The result in many cases has been that a great deal of the work that was projected had to be done all over again at great cost, or perhaps the whole contract was canceled, thereby causing great loss to the manufacturer.

My recommendation is that all companies doing work of this nature should first manufacture wholly standard stock material such as steps, curbs, copings, lintels, etc.; material that can be distributed among the building material dealers and which can be sold from stock; material that contractors can examine and buy; material that is not designed to follow architectural details; material that does not appeal to the artistic sense. Thus all unfair criticisms will be avoided and it will be possible to do a good business and to hold good customers with an increasing demand.

If such companies desire to become more ambitious and to imitate stone work as designed by architects, they can do so out of the earnings of the other business and not take the chances of having condemned work wreck them.

I do not believe that there has ever been an industry that has been so "knocked" as the concrete industry. It therefore behooves all those engaged in it to be sure that whatever they sell shall satisfy the purchaser, for if it does not do so that particular manufacturer is seriously injured and the whole concrete industry receives a blow. You are all familiar with the many publications distributed throughout the country, containing photographs of concrete buildings that have collapsed. Some of these

accidents have been very serious and great pains have been taken to publish broadcast the details, all for the purpose of hurting the business. I believe that we have happily passed beyond the period where important concrete work is entrusted to inferior builders who know very little about the subject, and that the work now and in the future will be handled by those experienced in the business. The companies engaged in concrete work are making good every time. For every dollar received they give a dollar's worth, and their customers are satisfied and want more. If this program can be carried out every time, we will soon see the last of the "Knockers."

I want to congratulate the Association upon the splendid exhibition here in Chicago, one of the most interesting I have ever attended. I also want to congratulate the city of Chicago that it has an opportunity to see what you are doing. This exhibition will do more towards educating the public that concrete has come to stay and is a fixture in our construction work in this country than anything else could do. The future for concrete is a brilliant one, and it behooves us all to guard it and watch it carefully, and so far as we can to permit no one to do any but good work.

I thank you.

The President:

Mr. Ewen has touched some vital points, points which this Association stands for. During the five years of existence of this Association I think it can be truthfully said that one of its fundamental objects has been to promote the proper use of cement by trying to instill into the minds of those who are using it a thorough and intelligent knowledge of how it should be used. I think the statement coming from a man of Mr. Ewen's standing that "we have passed the period where stories circulated for the purpose of discrediting concrete cease to do harm," touches a notable period in the concrete industry. There is no doubt that concrete is here to stay.

I am quite sure that we were all interested in Mr. Ewen's remarks and am certain that I voice the sentiments of the Association when I convey to him our appreciation and thanks.

The Assocation has been highly honored by the gentlemen who have come here this evening to formally welcome us to the city of Chicago, and I feel that the Convention will join me in extending to them a vote of thanks for their kindness, Mr. Bagby, the representative of the city of Chicago, Judge Kohlsaat and Mr. Ewen.

The following papers were then read and discussed:

"The Development of Concrete Road Construction," Fred R. Charles.

"The Use and Cost of Concrete Blocks in Roadway Construction," George C. Wright.

The report of the Committee on Roadways, Sidewalks and Floors was then presented by the Chairman, C. W. Boynton, embodying the following:

(*a*) Proposed Standard Specifications for Concrete Roadways.

(*b*) Proposed Standard Specifications for Portland Cement Curb and Gutter.

(*c*) Proposed Revision of the Standard Specifications for Portland Cement Sidewalks.

The Proposed Revision of the Standard Specifications for Portland Cement Sidewalks was discussed, amended and ordered to letter ballot.

The Proposed Standard Specifications for Portland Cement Curb and Gutter, and the Proposed Standard Specifications for Concrete Roadways, were referred for consideration to a regular session to be held at 2 o'clock on Wednesday afternoon, February 23.

The meeting then adjourned until Tuesday at 10.30 A. M.

TUESDAY, FEBRUARY 22, 1910, 9.00 A. M.

Meeting of the Section on Concrete and Reinforced Concrete.

President Humphrey in the chair.

This meeting was devoted to a topical discussion on the selection of materials, methods of construction, etc.

SECOND SESSION.—TUESDAY, FEBRUARY 22, 1910, 10.30 A. M.

President Humphrey in the chair.

The President announced, in view of the pending amendments to the By-Laws by which the President and the First, Second, Third and Fourth Vice-Presidents of the Associations are the only officers elected by the Convention, the Executive Board had anticipated favorable action by the Association and therefore decided to instruct the Committee on Nomination of Officers that they report only candidates for the President and

First, Second, Third and Fourth Vice-Presidents. In the event of the amendments to the By-Laws failing to pass, the Convention can then nominate Chairmen for the various sections.

The reason for this action on the part of the Executive Board is that under the present method the best qualified men have not always been selected for the various chairmanships, and furthermore, in many cases a plan of procedure inaugurated by a committee has been rendered void through the election of some other Chairman by the Association.

Many of the problems which are under consideration by the several sections do not admit of a final report in a single year. It is therefore necessary that the work should extend over several years. With a view to correcting this serious defect in the organization of the Association, it has been deemed desirable for the Executive Board to select the Chairmen for the various sections, since it has a more intimate knowledge of the work of each section, and is in a better position to select the man best suited for the chairmanship.

Through this means a Chairman who has shown proficiency in performing the work of his section can be continued in office several years, or until the work is so advanced that a change of chairman would not seriously affect the work. With these facts in view, the Committee on Nomination of Officers is so instructed, and the Executive Board announces the following Committee:

P. Austin Tomes, *Chairman,* New York, N. Y.
H. S. Doyle, Chicago, Ill.
P. S. Hudson, Louisville, Ky.
A. J. Maynard, State Farm, Mass.
H. H. Rice, Denver, Col.

This Committee will report at the business session of the Convention on Wednesday morning.

The Committee on Resolutions, to report at the last session, Friday evening, will be composed of:

Ernest McCullough, *Chairman,* Chicago, Ill.
Alexander C. Birnie, Ludlow, Mass.
Edward M. Hagar, Chicago, Ill.
O. U. Miracle, Minneapolis, Minn.
Emile G. Perrot, Philadelphia, Pa.
Ira A. Williams, Ames, Ia.

Mr. Olaf Hoff then read a paper on "Laying Concrete Under Water—Detroit River Tunnel," which was followed by a discussion.

A paper by Thomas H. Wiggin on "The Comparative Value and Cost of the Groined Arch in Large Reservoirs," was, in the absence of the author, read by title. .

The following papers were then read and discussed:

"Waterproofing Concrete," Cloyd M. Chapman.

"Preparation of Concrete—From Selection of Materials to Final Deposition," Harry F. Porter.

On motion, a recess was taken until 2.00 p. m.

Alfred E. Lindau, Chairman, then presented the Report of the Committee on Concrete and Reinforced Concrete, which was fully discussed.

The meeting then adjourned until 8.00 p. m.

THIRD SESSION—TUESDAY, FEBRUARY 22, 8.00 P. M.

President Humphrey in the chair.

President Humphrey stated that inasmuch as this is the natal day of the first President of our Country, it seemed appropriate for this National Association to make such a departure from the usual evening program as would be commemorative of the occasion.

President Humphrey made the following address:

In this introductory address I wish to dwell for a few moments on the life of Washington, and point out his close connection with the industry in which we are so deeply interested.

Among the first books relating to limes and cements it was my pleasure to read, was that which I hold, once the property of George Washington and now in the possession of Dr. George S. Webster, of Philadelphia, Pa. This book was published in 1780 by Dr. Bryan Higgins, on the title page, which bears Washington's signature, appears the following inscription: *Experiments and Observations made With the View of Improving the Art of Composing and Applying Calcareous Cements and of Preparing Quick-Lime: Theory of these Arts; and Specifications of the Author's cheap and durable Cement, for Building, Incrustation or Stuccoing, and Artificial Stone.*

It was this recollection of Washington's probable interest in cement that lead to some studies of his life which seem to indicate that he was one of the early users of cement in this country. It should be borne in mind, however, that the material which is to-day known as lime, was in those days called cement. That this material was of poor quality is indicated by the following extract from Dr. Higgin's book:

As the strength and duration of our most useful and expensive buildings depend chiefly on the goodness of the cement with which they are constructed, I looked to the improvement of mortar as a subject of great importance, in this country particularly, where the weather is so variable and trying, and the mortar commonly used is so bad, that the timbers of houses last longer than the walls, unless the mouldering cement be frequently replaced by pointing. But seeing that many years are requisite for the greatest degree of induration which cementitious mixtures like mortar can acquire, or for our discovering the imperfections of them; and that the life of man is too short to allow any considerable improvements of them to be derived from such experiments as had hitherto been made, I resolved in the beginning of the year 1775 to investigate more closely than I had hitherto done, the principles on which the induration and strength of calcareous cements depend; not doubting that this would lead me by an untried path to recover or to excel the Roman cement, which in aqueducts and the most exposed structures has withstood every trial of fifteen hundred or two thousand years.

It is probable that this material was made use of in the construction of the Potomac Canal with which Washington was early identified. You will recall that the use of cement in this country began in 1818, twenty-three years after Parker had obtained a patent for a material that he called Roman Cement. Canvas White at that time manufactured the natural cement which was used in the construction of the Erie Canal in which Washington was also interested, having made a reconnaissance for and an examination of the proposed route and predicted its commercial success.

Washington was identified with the promotion of our earliest canals, which mark the beginning of the cement industry in this country, and it is probable that the construction of the locks of the Potomac Canal, in which he was particularly interested, led him to acquire the book on limes and cements by Dr. Higgins.

George Washington began his career as a surveyor by taking a special course in surveying, although the facts relating to this period of his life are limited. Following this course in surveying he served an apprenticeship under Mr. James Genn, a licensed surveyor, and on July 20, 1749, was commissioned by the President of the William and Mary College to be the surveyor of Westmoreland County, Virginia. His proficiency as a surveyor at this age is remarkable, although he is said to have shown, at an early age, a marked aptitude for mathematics. He was connected with land surveys for several years, among his clients being Lord Fairfax.

In the latter part of the year 1753 Major Washington, then only twenty-one years of age, was delegated by the Governor and Council of Virginia on an important mission across the Alleghenies. He had been actively engaged three years prior to this surveying in the wilds of Western

Virginia and in the mountainous district at the headwaters of the Potomac River. He had acquired so high a reputation for energy, firmness and decision, besides possessing a thorough knowledge of the particular feelings and prejudices of the Indians and a practical acquaintance with the mode of living and traveling, which had accustomed him to the hardships and privations of camp life, as to attract the attention of Governor Dinwiddie as the most suitable person to undertake this mission; in the subsequent years of 1770, 1772 and 1774 he made several trips, examining the best route across the Alleghenies.

It was undoubtedly this early training as a surveyor that gave him his knowledge and ability as an engineer, and while to Major L'Enfant is given the credit for the preparation of the plans of what is now the City of Washington, it was, nevertheless, Washington who directed the work and selected the final site for the Capitol.

These facts, as interesting as they are to us, form but an incident in the life of Washington and the conspicuous part he played in the affairs of this country during one of the most eventful periods in the history of the world. His many qualities in all that relates to his public and private life form "altogether such a union of goodness and greatness in the character of one individual as to excite the warmest interest and command the admiration of mankind."*

He was great and good in all the positions he held—from a study of his first work as a member of a surveying party in the wilds of the Allegheny mountains, later as a special messenger from the Governor of Virginia to the Commandant at the Ohio, at the memorable defense of the stockade, at Great Meadows, then at the head of his regiment upon the plains of the Monongahela and later as the Commander-in-Chief of his countrymen, it would seem that his early career must have given him the experience and knowledge which made him a military engineer of no mean ability.

Upon resigning his commission as Chief of the Army of the Revolution, he retired to Mount Vernon, where, as he so feelingly expressed it, "he hoped to spend the remainder of his days in cultivating the affection of good men and in the practice of domestic virtues."

He had, however, enjoyed the quietude of his retirement for a few months when he left Mount Vernon on his first tour of the West at the close of the Revolutionary War, and on the first day of September, 1784, after having completed the examination of several routes across the mountains and the headwaters of streams which he proposed to connect, he returned to Mount Vernon in the fall of 1784.

He was deputized on behalf of the State of Virginia to serve on the Commission to meet with the General Assembly at Annapolis, of which commission he was chosen Chairman, and its report forms the basis of the

* See "A New Chapter in the early life of Washington in connection with the narrative history of the Potomac Company," by John Pickell. 1856.

legislative action upon which the Potomac Company was inaugurated and organized. This company elected George Washington its first President in 1785, from which he retired in 1788.

Washington was the active advocate of many of our great highways—he not only prepared the first plans and recommended the construction of the national pike and the Chesapeake and Ohio Canal, but he also was the first to recommend the route through the Mohawk Valley, which was afterwards followed by the Erie Canal and the New York Central Railway. The route of the National Pike between the Great Falls of the Potomac to Pittsburgh was planned and constructed under his direction.

Washington may therefore be justly regarded as the Father of the Cumberland National Route, Chesapeake and Ohio Canal and the Baltimore and Ohio Railroad, for it was to the doors in the Alleghenies that Washington was looking with anxious eyes at the close of the Revolution, and his connection with the Potomac Company was reluctantly severed when, upon the commands of the people, he assumed the office of the first President of the United States.

After a lapse of many years, the project of connecting the east and west through the Valley of the Potomac, and that of the most convenient tributary to the Ohio west of the mountains, was revived in 1823 in the form of a project for continuous canal navigation. In the consummation of this project the rights and privileges of the Potomac Company were surrendered to the Chesapeake and Ohio Canal Company and the original papers deposited in the office of that company. A study of these interesting records show that Washington had active connection with the construction of this canal.

This book by Dr. Higgins on the properties of limes and cements may be considered as evidence that Washington acquired it for the purpose of familiarizing himself with the material that was probably used in the construction of the locks of that canal in which he was interested.

The discussions of the properties of limes and cements by Dr. Higgins is exceedingly interesting as indicating the problems which confronted the manufacturers of the time of Washington. In the course of this discussion the writer states that,—

> All these experiments and observations conspire to point out the circumstances in which mortar becomes indurated the soonest and in the highest degree, and operates most effectually as a cement. To this end it must be suffered to dry gently and set; the exsiccation must be effected by temperate air and not accelerated by the heat of the sun or fire: It must not be wetted soon after it sets; and afterwards it ought to be protected from wet as much as possible, until the mortar is finally placed and quiescent: and then it must be freely exposed to the open air as the work will admit, in order to supply acidulous gas, and enable it sooner to sustain the trials to which mortar is exposed in cementitious buildings and incrustations.
>
> From these considerations we learn other causes, besides those already mentioned, of the speedy ruin of our modern buildings.
>
> The mortar made with bad lime and a great excess of it, and debased in watering and long exposure, is used with dry bricks and not unfrequently with warm ones. These

immediately imbibe or dissipate the water and not only induce the defect above noticed, but, as the cement approaches nearer to be dry, whilst it is still liable to be disturbed by the percussions of the workmen, render it more nearly equivalent to a mixture of sand and powdered chalk.

But to make strong work the bricks ought to be soaked in lime water, and freed from the dust, which in common bricklaying, intercedes the brick and mortar in many parts. By this method the bricks would be rendered closer and harder; the cement, by setting slowly, would admit the motion which the bricks receive when the workman dresses them, without being impaired; and it would adhere and indurate more perfectly. The same advantages would attend the soaking of bibulous stones in lime water, and the use of grout; provided this were made with good lime sand and lime water.

Many of these problems being still under consideration at the present time, although in the century and a quarter that has elapsed since this book was written a most remarkable change has taken place both as regards the quality and in the development of the use of cement. From the above quoted remarks of Dr. Higgins it is quite evident that the cement of to-day far excels the cement of his time, and it is further evident from the following quotation that the cement described by Dr. Higgins excelled the cement of antiquity whose properties he sought through experiments to equal or excel:

With regard to the objections grounded on our short experience of this cement, I think they can have very little influence amongst informed men who know, from the writings of the antients, by the inspection of old cements, and by the analysis of them, that mortar made of lime and sand can endure every trial of the weather in the most exposed situations for a thousand years or more.

I am aware of the opinion, which is prevalent at this time, that the antients used something which is unknown to us in their mortar, and that this long lost ingredient is the cause of the duration and hardness of those cements, which we so much admire in some of their structures. A notion founded on conjecture does not demand a serious discussion. I will therefore treat it as a subject of conversation rather than of argument.

The same ignorance of the nature of lime is betrayed by Alberti and later writers. And since we do not find any scientific rules prescribed by literary artists, for the composition of calcareous cements with such chosen and sorted materials as I have described, or in such proportions of them; and since it is highly improbable that the remembrance of an useful ingredient, or any knowledge once acquired in an art practised in so many countries and by so many different persons in every age, should have been lost; we have the most satisfactory reasons for concluding that the antients had no skill beyond that of our modern builders, in the preparations of lime or mortar.

The ruins of Herculaneum and other reliques of their work, furnish us with abundance of bad mortar and defective incrustations, which are instances of their ignorance of those principles by which the best cement might be equally cheap. The total ruin and obliteration of many of their buildings, argue to the same end; for well cemented works suffer very little by dilapidation, by reason of the difficulty and expense of pulling them to pieces and applying the materials to other structures. If to these considerations I can add an exposition of the fortuitous circumstances which rendered some of their cements uncommonly hard and durable, I hope I shall not be suspected of ungenerous invidious motives, in saying that the aqueducts and other structures, which have been preserved to us through so many ages, by the strength of their cement, are monuments rather than of the good luck, than of any extraordinary skill, of those who built them.

In the concurrence of these circumstances, we find excellent cements of great antiquity which I need not point out to literary men: but since they are found no where else, that I have discovered; and since it is not probable that the antients had any art of this kind unknown to the moderns I think I am authorized to conclude that their best cementitious works, instead of being held forth as instances of their unequalled skill, ought rather to be considered as substantial proofs of the duration of mortar or stucco duly

composed of sand and lime, beyond all others, and of the utility of these endeavours which I have made for preparing calcareous cements according to scientific principles, which enable us to make them in the highest perfection in all places, and to accommodate them to every purpose of use or ornament.

It is also evident that Dr. Higgins had to contend with the same opposition that many users of cement experience to-day, and,

in order to guard against abuses, and to make some compensation for the expenses and risques of the artists who publicly and boldly executed, on a great scale, what I had designed; I secured an exclusive right in my cement, by virtue of his majesty's letters patent, on the eighth of January, 1779. I authorized Mr. James Wyatt the architect of Queen-Ann street, Cavendish-Square, to use it in the fullest extent knowing that he, by his knowledge of this subject and his distinguished taste in architecture, will unite in it all the advantages of duration and elegance; I likewise extended this right to Samuel Wyatt, the builder in Berwick-street, Soho, who is well instructed, and provided with the means of executing any work with this cement, in the highest perfection; and I intend to reserve this privilege to them, until the public convenience requires that it should be extended to others, who are capable of making the same dispositions for the benefit of their employers, and for preserving the reputation of my invention free from the usual exactions of monopolists and the abuses of under-jobbers.

Dr. Higgins had also to contend with the inexperienced workman with which we are familiar to-day, and records the facts in the following:

The inexperience of the workmen, their obstinate adherence to their own notions, and the opinion which they entertained that some of the rules prescribed to them were insisted on rather through an affectation of mystery than for any useful purpose, operated strongly against the best endeavors of Messieurs Wyatt, in the incrustations first made on the great scale for use or ornament. In consequence of these disadvantages which will be obviated in future, their stucco, although it excels others beyond comparison and is far from being perishable, is not quite so hard as it might have been made. This I mention lest these incrustations should be mistaken for the best, which I have represented as exceeding Portland stone in hardness. These last demand a strict observance of the foregoing precepts respecting the season and the exposure as well as the materials and mechanical application of them.

It is evident that the cement of Dr. Higgins' time, in that it was more uniform and was scientifically prepared, excelled the cements which have been handed down from antiquity. It is also evident that the material which he called cement, and which we call lime, is far excelled by our Portland Cement.

It is also a matter of interest to note that the need for a fire-resistive type of building was apparently a matter of as much importance in those days as it is at the present time, and in evidence thereof I beg leave to again quote Dr. Higgins:

The public are indebted to Mr. Hartley for the experimental proofs he has given of the efficiency of his method of securing houses from fire; and to Lord Mahon for those judicious and expensive experiments by which he has shown that a calcareous incrustation answers the purposes of Mr. Hartley's art. I am afraid that their good intentions will be frustrated by the indifference of men to distant or improbable evils, and their dislike to any immediate expense which affords no extemporary convenience or ornament. But although such motives of economy should dissuade us from adopting their measures in the fullest extent, we ought certainly to avail ourselves of the useful knowledge which they have imparted, so far as to prefer a safe and durable stucco, wherever it is applicable by the assistance of hair before wainscot or wooden ornaments. For although no metallic or calcareous

covering can secure the wood of a house from being charred by a great fire, the danger of others is lessened as the combustible materials are secured from the action of the air and consequently from contributing to the deflagration.

Again, it is interesting to note that Dr. Higgins touches on cement roadways, which is one of the subjects now being actively considered by the Association, in the following manner:

I have thought that the small stones, which constitute the gravel chosen for our roads, could not be reduced to dust so soon as they now are, by the heavy carriages, if they were firmly bedded in a small quantity of coarse and good calcareous cement, so that the bodies which roll over them should rather compress them, than grind them against each other as they do at present. And as the frequent failures of pavement are manifestly owing to the infirmness of the ground and the looseness of the stones, I have imagined that a solid bed cf cementitious work, in the manner of the Romans, and the setting of the paving stones in good mortar, would ultimately lessen rather than enhance the expence. I offer these conjectures in the hope that nobody will presume to decide on the subject, who does not know the difference between the common mortar, and the best that can be made of lime and sand; and that some public-spirited man will make the experiment, where lime is cheap and the expence of pavement or of gravel is considerable. If the expence should be found too great for any public works of this kind, the same may nevertheless be tried in private areas and walks, in which the neatness, duration and prevention of vegetation, may compensate for the extraordinary price.

These interesting topics, which were considered nearly a century and a half ago, are now under consideration and tend to prove that there is, after all, "nothing new under the sun."

While the principle of the function of cement may not be new, the development since the time of Washington in its quality and the uses to which it is put has been miraculous.

Certain it is that the present vastly surpasses any previous period in the history of the use of cement.

Washington's connection with the location and construction of the earliest canals of this country, which played such a prominent part in the development of the cement industry, should be a matter of deepest interest to the members of this Association. It is because of this possible interest that it has been my pleasure to bring to your attention this chapter in the life of this great man, whose memory it is our privilege each year to honor.

An address on George Washington was delivered by John A. Northrop, Assistant State's Attorney, Cook County, Chicago, Ill., in place of John A. Wayman, State's Attorney, who was detained by illness:

Mr. Chairman and Gentlemen: It is a matter of deep regret with Mr. Wayman that he is unable to keep his appointment with you this evening. Late this afternoon he telephoned me that by reason of illness he would be unable to be here to-night, and requested that I appear instead.

While sitting here it has occurred to me that the subject of cement

comes home to all of us in ways unthought of before. We can scarcely open our eyes without seeing evidences of that great industry, over which you grow enthusiastic, and it requires no stretch of the imagination to see that it will draw vastly more upon the enthusiasm of the future.

It is noteworthy that Washington, as your President has pointed out, so long ago realized the possibilities in the use of cement. It attests his marvelous many-sidedness, his wonderful power of observation, that he so early perceived the value of this product, that he foresaw a great industry which to-day holds the center of the stage.

But Washington was an earnest advocate of another cement, the cement of national unity. With prophetic vision he clearly saw that the colonies could accomplish little without union. He found that their interests were inharmonious and often hostile. Each feared the loss of its own power and prestige in the growth of rival colonies. Even in the face of imminent danger they were ready to fly at each other, or to abandon each other by reason of jealousy or fear. All through the Revolution this fact arose to vex and hamper the cause of freedom. At all times it was present to endanger any success of arms which Washington might achieve. However skillful he might plan his campaigns, however brilliantly he might execute them, this spectre arose to threaten disaster.

Therefore, it was that Washington deeply realized that the greatest need of the times was a spirit which would cement the colonies into an unbreakable union. Here were the elements of an imposing edifice. How to weld them into a durable and harmonious structure was an idea ever uppermost in Washington's mind. How the blood and the tears and the sacrifice and the hopes of that heroic epoch entered into the making of a cement which at last was strong enough to hold the union indissoluble forever, we well know. But the forming and the setting of the cement was a slow and painful process. When the last shot of the Revolution was fired, it was still far from complete. Indeed for a time thereafter we entered *the most critical period of American history.* The sword of freedom had indeed won its battle, the last "Red Coat" had departed from our shores, yet the old jealousies and rivalries flamed up more brightly than before. There was bitterness and danger of clashes along many a colonial boundary. Up among the hills to the North, the citizens of New Hampshire, and the Green Mountain boys patrolled the border with jealous and unfriendly eyes. Everywhere was apprehension, fear and distrust. Things seemed to be drifting into a chaotic condition where the results of glorious achievements should be forever lost. With almost infinite patience, with a vision far into the future, Washington labored to create a national sentiment. This work was carried on with all the splendid genius of Hamilton and Marshall and Webster. At last in the tears and blood of the Civil War, the cement of the national unity was firmly and forever set. Washington's vision was realized at length, and what had been but fragments were drawn into a mighty and indissoluble arch.

I shall dwell but briefly upon the earlier life of Washington. Your

chairman has given you a comprehensive account of his earlier exploits. I shall merely call attention to a few of his characteristics which we may always contemplate with profit and interest.

Washington's noteworthy achievements began when he was little more than a youth, yet such was his judgment and the confidence which he inspired, that men rallied to him on the field of battle, and relied on him in the councils of state. He had a bearing, a poise, and a stately quality of character which made him a natural leader of men.

When we recall that Washington was summoned from his Virginia home to the elms there at Cambridge, to assume charge of an army which was little more than a mere rabble, and when we reflect what is necessary to provision, to organize and to discipline such a body of men in order to make it an effective power in war, we realize but faintly the task which confronted him. The raw levies of militia placed at his command had for the most part never seen a day's service in battle. In numbers, in equipment, in discipline, in organization, in everything which goes to make up an effective army, save physical valor alone, they were inferior to the foe. With such an army Washington was called upon to confront in fierce and bitter warfare, the most powerful nation of the earth. How well he did his part; how campaign followed campaign; how he was compelled to follow the tactics of Fabius in retreat after retreat; how he was bitterly assailed and criticized at the time for nearly all that he did and for what he did not do; how unfair and cruel he knew that criticism to be; how, for the common good, he ignored the cruel slings and thrusts, is familiar to us all; yet through all the fearful experience, in the bitterness and the blood at Valley Forge, in the reverses which befel his arms at Long Island, Brandywine and Germantown, in the desperation of retreat, his hope and his courage were never broken, and his army, though sorely depleted, was never once permitted to break up into a demoralized band. Out of the darkest gloom he was ever ready to strike a blow which might change the fickle fortunes of war. This very desperation led him over the icy Delaware and nerved his army to splendid triumph at Trenton, brought signal victory at Princeton, and led on to battle at Monmouth under such prospects of success that he fondly hoped the end was at last in sight. It was no fault of his that General Charles Lee, commissioned by the Continental Congress to lead the attack in this crucial battle, at the supreme moment failed him and failed the country. It but illustrated that a faction in the Continental Congress was ever ready to override his judgment, and how treachery and jealousy in the army were ready, in striking at him, to strike at the cause for which he so nobly stood.

It was the very cruelty and treachery of the circumstances with which Washington contended that best brought out the splendor of his character. It was in meeting these that we saw the real caliber of the man. Beyond all the intrigues and rivalries and jealousies of the hour, such as that which created the Conway Cabal, he looked to the nobility of his own spirit, and the nobleness of the cause for which he fought, for final justi-

fication. To what splendid advantage he appears when his judgment is tested by that of the Continental Congress. In that test he was nearly always right, and the Congress nearly always wrong. He advised against the holding of Fort Washington on the Hudson, against the sending of General Gates to take command of the Southern army, and again he was justified by events. In nearly every instance where the Congress acted upon his advice, success and triumph followed the colonial armies.

But while individuals and factions here and there tried to foil the mighty purposes of Washington, the great majority yielded him their unmeasured confidence. His patriotism none could question; his high and lofty purpose was well attested when he said to the country, "My life and services are at your command. I ask no compensation for services in the field. I ask only when war shall have passed that I may be repaid the money I have advanced in the common cause." In triumph Washington had no scores to settle with those who had cruelly struck at him and the cause for which he fought. Unmindful of it all he pursued his purpose down to "Yorktown's glorious day," where in the vindication of triumph he forgot the darkness of the past and became enshrined in the public heart. He was surrounded by a soldiery whose loyalty and love were linked with his interests in the bitterness of defeat, and in the sweetness of victory; a soldiery which venerated him as the noblest spirit of earth; a soldiery more loyal to its commander than were the legions of Cæsar or the battalions of Napoleon. Little wonder that these companions in arms sought to call him king and sought to create for him a throne. But the very thought was alien to the nature of Washington, and so wisely and so firmly did he reject the unwelcome idea, that it never became necessary for him, as it did for Cæsar, to thrice reject a kingly crown.

But I have talked long enough upon the familiar story of Washington's characteristics. The American people can never fail to be instructed by studying his disinterested and lofty purpose. This is to be borne in mind when we contemplate a great character: even greater than the work which he achieves in his day and generation is the example which he gives to all succeeding ages. He may be great as a statesman, great as a warrior, great as a patriot, but he is incomparably greater as an exemplar. When you recall that in the wilderness of Kentucky and Indiana, the boy Lincoln drew his deepest inspiration from that quaint biography of Washington written by Weems, that the life and purposes of Washington became in a way the shaping force in the life and purposes of Lincoln, we realize the power of example. And all over this broad land the boys and girls were being influenced to patriotism and to higher purposes by studying that same great life. It would scarcely be too much to say that in the great struggle to save the Union, the spirit of the North drew its deepest inspiration from the noble example of Washington.

As the representative of a great industry which is scarcely yet more than in its infancy, you gentlemen will have a great part to play in the

progress of our times. How swift our material development has been we can scarcely realize. In speaking at the centennial of Washington's birth, in 1832, Webster characterized that century as the most marvelous one in history, remarking that it had accomplished more than fives and tens of centuries preceding it. Those of you who have seen the old carriage in which Webster rode, now a relic in the Field Museum, realize that the advancement in transportation and material matters has been incomparably greater since the time when Webster spoke than during any time before. If the men of any preceding generation could return to earth and behold the evidences of material progress we can scarcely conceive their amazement. When we think of the wonders of wireless telegraphy, the wonders of aviation, the wonders wrought by the application of scientific principles to the uses of men, we can see no limit to the possibilities of the future. Science has penetrated the mountains and the seas, to lay tribute to man's use, the vast sources of nature. It has attacked every enemy of humankind. It has sought out those invisible monsters, which, lurking in the air we breathe and in the food we eat, breed contagion and pestilence. With his test tube and crucible, with his reactive agents and his toxins the scientist has set these foes of humankind into a warfare of mutual extermination in the whirling currents of the blood; he has brought them to their Waterloo upon the battlefield of a human tonsil.

One of the greatest demands made upon science in these modern days is the effort to conserve our resources, and in that connection you gentlemen may be characterized as genuine conservators. I am told that you make everything which man needs during and after his life with cement; that from the time we are ushered in upon this earthly scene we are likely to be cradled in cement, to live in houses of cement, to do life's work through instrumentalities of cement, and finally when we are shuffled off this mortal soil our remains are to be laid away in coffins of cement, to await the sound of the final trumpet. You are, therefore, no less benefactors in the race than he who makes two blades of grass grow where but one had grown before. When you commit our mortal dust to the dust of mother earth in caskets of dust, you leave the trees which else had been wrought into our last covering to wave in the forests, or to be used for living and not the dead. You are all the more true conservators, in that you draw upon a material which otherwise would remain inert and useless for all time. Now, we behold this otherwise useless material rising into splendid edifices, into beautiful cities, and taking on many forms expressive of our civilization.

These wonderful changes of the physical world have wrought a vast effect upon the organization of industry, and upon the political life of the people. Industry has been organized on a vast and intricate scale, great corporations and trusts have grown up. Scarcely less wonderful to the fathers if they could reappear upon the earth, would be these changes in the organization of industry than the wonders of invention, and the

progress of science. It is a favorite diversion with some people to wonder how earth's departed great would view these modern wonders; to wonder what they would approve and what they would condemn. The hobbyist is ever ready to believe that the spirit of Lincoln or of Washington would set its approval upon his own particular view. And so believe those who most loudly cry that the times are out of joint, and that ruin inevitably awaits our tendencies. But there is nothing in the life of Washington or of Lincoln that would warrant any departure from the firm and established principles on which our institutions are based. Some things they might disapprove, but we can be sure that they would implore us to keep in mind the great landmarks of the past, to keep our feet firmly planted upon the solid foundation upon which the republic was established. This fact ought to be self-evident: that those manifold powers of the human mind which have called into being, which have evoked the great forces of industrial activity about us, which have created the wonders of the modern world, may be trusted in the end to properly control those vast forces for the common benefit. It is taking a small view of human nature and a small view of the American citizen to believe that because the human mind has discovered and applied wonderful forces of nature to the uses of man, whereby the organization of industry has been vastly changed, that therefore the institutions which our fathers gave us are to be torn from their foundations. The power of mind which produced these great changes may not at once discover the best method of controlling them for the common good, but that it will eventually do so, is certain. Nor in my humble judgment is this to be accomplished by the many panaceas which lose sight of the ideas and the ideals of the founders of the Republic. It will be accomplished consistently with the principles upon which our great commonwealths have been established, and our splendid cities created. They will realize in the long run that these wonders of the modern world are not ends in themselves, but merely the means whereby humanity is to be made better and happier. This realization will come about without revolution, without any overturning of the institutions which we have, and all the wonders of industry and of science will find their place under our government and under the constitution. All will be wisely controlled and adjusted by the sober second thought of the American people, and come to serve their purpose as have the best institutions of the past.

In closing I desire to call your attention to brief tributes paid to the character of Washington, by some of the greatest men that ever lived. Many of these have come from great Englishmen. Lord Erskine declared in a communication to Washington, "You are the only being for whom I have an awful reverence." Lord Brougham, in speaking of Washington, said, "Until time shall be no more will a test of the progress which our race has made in wisdom and virtue be derived from the veneration paid to the immortal name of Washington." Gladstone paid his tribute in these words, "If among all the pedestals supplied by history for public

characters of extraordinary nobility and purity, I saw one higher than all the rest, and if I were required at a moment's notice to name the fittest occupant for it, my choice would light upon Washington." There have been many who were disposed to deny Washington the meed of military genius, but as his campaigns have been studied from a disinterested standpoint, the better opinion has come to coincide with that of Frederick the Great, who, in commenting upon the exploits of Washington before and after the battle of Trenton, characterized them as, "The most brilliant achievements in the annals of military action." In 1842, Abraham Lincoln, in an address upon Washington at Springfield, said, "This is the one hundred and tenth anniversary of the birthday of Washington; we are met to celebrate it. Washington is the mightiest name of earth—long since mightiest in the cause of civil liberty, still mightiest in moral reformation. On that name no eulogy is expected. It cannot be. To add brightness to the sun or glory to the name of Washington is alike impossible. Let none attempt it. In solemn awe pronounce the name, and in its naked, deathless splendor leave it shining on."

And so we to-night can add no glory to the twin luminaries, Washington and Lincoln. It is enough to pronounce their names in solemn awe, and leave them shining on in all their deathless glory.

Regretting, gentlemen, that Mr. Wayman could not be here this evening, and thanking you for the attention which you have given me, I close.

The President:

While we deeply regret the fact that Mr. Wayman could not be with us, we have enjoyed Mr. Northrop's thoroughly interesting address, and we are thankful to him for his goodness in coming this evening.

The program, after a musical selection, calls for Washington's Farewell Address, and following that will be musical numbers, humorous recitations and other matters of that kind. I hope that you will all remain and see if we cannot get away from the serious tone that has heretofore marked all our sessions.

After the close of the entertainment the Convention adjourned until Wednesday morning at 9.00 A. M.

WEDNESDAY, FEBRUARY 23, 1910, 9.00 A. M.

Meeting of the Section on Specifications for Cement Products.

President Humphrey in the chair.

Discussion on the Manufacture, Curing, etc., of Cement Hollow Building Blocks, Architectural Concrete Blocks, etc.

FOURTH SESSION—WEDNESDAY, FEBRUARY 23, 1910, 10.30 A. M.

President Humphrey in the chair.

W. P. Anderson, Chairman, read the report of the Committee on Specifications for Cement Products, presenting,

(*a*) Proposed Standard Specifications for Architectural Concrete Blocks.

(*b*) Proposed Standard Specifications for Plain Concrete Drain Tile.

The following action was taken on this report:

The Proposed Specifications for Plain Concrete Drain Tile were referred back to the Committee with instructions to confer with the Committee of the Interstate Tile Manufacturers' Association, and to report to the Convention.

The Proposed Standard Specifications for Architectural Concrete Blocks were discussed and referred to the Special Session at 2 P. M.

The report of the Committee on Machinery and Appliances was, in the absence of the Chairman, L. V. Thayer, read by title.

Business Session.—The report of the Executive Board and the Minutes of the Meetings of the Board were approved as read.

The following proposed amendments to the By-Laws were approved and ordered to letter ballot.

Amend Article I by striking out Section 5 and inserting a new Section 5 to read as follows:

SECTION 5. Resignations from membership must be presented in writing to the Secretary within thirty days after the close of the fiscal year and shall be acceptable provided the dues are paid for that year.

Strike out Article II and insert a new Article II as follows:

SECTION 1. The officers shall be the President, the Vice-Presidents, Secretary and the Treasurer, who, together with the five latest living Past-Presidents, shall constitute the Executive Board. Vacancies occurring during the year shall be filled by the Executive Board.

SEC. 2. The Elective Members of the Executive Board consisting of the President, the First, the Second, the Third and the Fourth Vice-Presidents, shall be elected annually by ballot at the convention at a business session fixed by the Executive Board and shall hold office until their successors shall qualify.

SEC. 3. The Elective Members of the Executive Board shall appoint the Secretary and the Treasurer; they shall create such special committees as may be deemed desirable for the purpose of preparing recommended standards concerning the proper use of cement for consideration by the Association, and shall appoint a chairman for each committee who shall be a Vice-President of the Association. Four additional members on each special committee shall be appointed by the President, in consultation with the Chairman.

SEC. 4. It shall be the duty of the Executive Board to audit the accounts of the Secretary and the Treasurer before each annual convention.

SEC. 5. The Executive Board shall appoint a Committee on Nomination of Officers and a Committee on Resolutions, to be announced by the President at the first regular session of the annual convention.

SEC. 6. There shall be an Executive Committee of the Executive Board consisting of the President, the Secretary, the Treasurer and two of its members, appointed by the Executive Board.

SEC. 7. The Executive Committee shall manage the affairs of the Association during the interim between the meetings of the Executive Board.

SEC. 8. The President shall have general supervision of the affairs of the Association. He shall preside at the Annual Convention, at the meetings of the Executive Board and the Executive Committee, and shall be ex-officio member of all committees.

The Vice-Presidents in order of seniority shall discharge the duties of the President in his absence.

SEC. 9. The Secretary shall perform such duties and furnish such bond as may be determined by the Executive Board.

SEC. 10. The Treasurer shall be the custodian of the funds of the Association and shall disburse the same in the manner prescribed by the Executive Board. He shall furnish bond in such sum as the Executive Board may determine.

SEC. 11. The Secretary and the Treasurer shall receive such salaries as may be fixed by the Executive Board.

Amend Article III to read as follows:

SECTION 1. The Association shall meet annually. The time and place shall be fixed by the Executive Board and notice of this action shall be mailed to all members at least thirty days previous to the date of the Convention.

SEC. 2. The Executive Board shall meet during the Convention at which it was elected, effect organization, and transact such business as may be necessary.

SEC. 3. The Executive Board shall meet at least twice each year. The time and place to be fixed by the Executive Committee.

Amend Article IV to read as follows:

Section 1. The fiscal year shall commence on the first of July and all dues shall be payable in advance.

Sec. 2. The annual dues of each member shall be five dollars ($5.00).

Sec. 3. A member whose dues remain unpaid for a period of one year shall forfeit the privilege of membership and shall be officially notified to this effect by the Secretary, and if these dues are not paid within thirty days thereafter his name shall be stricken from the list of members. Members may be reinstated upon the payment of all charges upon the books of the Association.

Amend Article VI to read as follows:

Section 1. Amendments to these By-Laws, signed by at least three members, must be presented in writing to the Executive Board prior to November 1st and shall be printed in the notice of the annual convention. These amendments may be discussed and amended at the annual convention and passed to letter ballot by a two-thirds vote of those present. Two-thirds of the votes cast by letter ballot shall be necessary for their adoption.

Edward D. Boyer, Chairman, presented the report of the Committee on Contributing Membership.

The place for the next Convention was then considered, and an invitation extended on behalf of Atlantic City by Geo. S. Lehnhart, and communications were read from Chattanooga, Tenn., Cincinnati, Ohio, Rochester, N. Y., and St. Louis, Mo. The final selection of the place for the next Convention will be made by the Executive Board.

The Committee on the Nomination of Officers, Austin P. Tomes, Chairman, made the following report:

President, Richard L. Humphrey, Philadelphia, Pa.

First Vice-President, Edward D. Boyer, Catasauqua, Pa.

Second Vice-President, M. S. Daniels, Suffern, N. Y.

Third Vice-President, E. S. Larned, Boston, Mass.

Fourth Vice-President, F. A. Norris, Boston, Mass.

On motion duly seconded, the Secretary was instructed to cast a unanimous ballot for the election of these officers.

On motion, the following Resolution was adopted:

Resolved, That the Association extend to Mr. Merrill Watson and Mr. George C. Walters a vote of thanks as an expression of appreciation for the faithfulness and untiring zeal exercised in the discharge of the duties of their respective offices.

The meeting then adjourned until 2.00 p. m.

FIFTH SESSION—WEDNESDAY, FEBRUARY 23, 1910, 2.00 P. M.

President Humphrey in the chair.

This session was devoted to a discussion of the Proposed Specifications for Concrete Roadways, for Portland Cement Curb and Gutter, and for Architectural Concrete Blocks.

After discussion, the Proposed Standard Specifications for Portland Cement Curb and Gutter were revised and approved for letter ballot.

The Proposed Standard Specifications for Concrete Roadways and Street Pavements were then considered, amended and approved for letter ballot.

The Proposed Specifications for Architectural Concrete Blocks were thoroughly discussed and referred back to the Committee for the collection of more data and further study.

The meeting then adjourned until 8.00 P. M.

SIXTH SESSION—WEDNESDAY, FEBRUARY 23, 1910, 8.00 P. M.

President Humphrey in the chair.

Richard L. Humphrey presented the Annual Address of the President on "The Use of Concrete in Europe."

The following papers were then read and discussed:

"Reinforced Concrete Columns," Peter Gillespie.

"Proposed Method for the Reinforcement of Concrete Compression Members," Robert A. Cummings.

"Longitudinal Reinforcement in Concrete Columns," Sanford E. Thompson.

"Discussion of the Reinforcement of Concrete Compression Members," L. S. Moisseiff, read by title.

The meeting then adjourned until Thursday at 10.30 A. M.

THURSDAY, FEBRUARY 24, 1910, 9.00 A. M.

Meeting of Sections on Building Laws and Insurance, and on Specifications for Fireproofing.

President Humphrey in the chair.

The meeting took the form of an informal discussion on fire-resistive construction of buildings, building regulations, and their effect on insurance rates.

SEVENTH SESSION—THURSDAY, FEBRUARY 24, 1910, 10.30 A. M.

President Humphrey in the chair.

Report of the Committee on Building Laws and Insurance was presented by the Chairman, W. H. Ham, covering the following:

Part I. Proposed Standard Building Regulations for the Use of Reinforced Concrete.

Part II. Report on Insurance.

The Proposed Standard Building Regulations for the Use of Reinforced Concrete were amended and approved for letter ballot.

The Report on Insurance was accepted as read:

The report of the Committee on Specifications for Fireproofing was read by Rudolph P. Miller, Chairman.

The following papers were then read and discussed:

"Simple Method of Computing the Strength of Flat Reinforced Concrete Plates," Angus B. MacMillan.

"Long Span Light Floor Reinforced Concrete Construction with Cost Data," Emile G. Perrot.

"Cost Data on Reinforced Concrete Floor Construction with Separately Molded Members," Charles D. Watson.

The meeting then adjourned until 8.00 P. M.

EIGHTH SESSION—THURSDAY, FEBRUARY 24, 1910, 8.00 P. M.

President Humphrey in the chair.

A paper by J. H. Libberton, on "Cost and Advantages of Concrete Drain Tile" was read and discussed.

The Committee on Cement Products then presented the Revised Proposed Specifications for Concrete Drain Tile as

amended by the conference between the members of the Committee and the Committee of the Interstate Tile Manufacturers' Association.

The Proposed Specification was discussed, amended and referred back to the Committee with instructions to gather more data and report at the next Convention.

The Committee on Roadways, Sidewalks, and Floors then presented the following specifications revised as instructed by the Convention:

(*a*) Proposed Revised Standard Specifications for Portland Cement Sidewalks.

The Proposed revised Specification was amended and approved for letter ballot.

(*b*) Proposed Standard Specifications for Portland Cement Curb and Gutter.

The proposed specification was amended and approved for letter ballot.

(*c*) Proposed Standard Specifications for Concrete Roadways and Street Pavements.

The Proposed Specifications as revised, was amended and approved for letter ballot.

A paper by F. S. Phipps on "The Installation and Operation of a Steam Curing Plant" was then read and discussed.

In the absence of the author, a paper on "Essentials in Cement Hollow Block Construction," by Ernest B. McCready, was read by title.

The meeting then adjourned until Friday at 10.30 A. M.

FRIDAY, FEBRUARY 25, 1910, 9.00 A. M.

Meeting of the Sections on Art and Architecture, on Exterior Treatment of Concrete Surfaces and on Machinery and Appliances.

President Humphrey in the chair.

The meeting was devoted to a topical discussion on the artistic treatment of concrete surfaces of various kinds.

NINTH SESSION—FRIDAY, FEBRUARY 25, 1910, 10.30 A. M.

President Humphrey in the chair.

The following papers were read and discussed:

"Inexpensive Homes of Reinforced Concrete," Milton Dana Morrill.

"Notes on the Use and Cost of Concrete for Small Houses," C. R. Knapp.

The following Committee reports were then presented:

Report of the Committee on Art and Architecture, F. A. Norris, Chairman, read by title in the absence of the Chairman.

Report of the Committee on Exterior Treatment of Concrete Surfaces, L. C. Wason, Chairman. This report was read and discussed.

A paper by S. Cunningham, Jr., on "The Use of Concrete for Farm Buildings from the Sanitary Point of View," was, in the absence of the author, read by the President.

The meeting then adjourned until 8.00 P. M.

TENTH SESSION—FRIDAY, FEBRUARY 25, 1910, 8.00 P. M.

President Humphrey in the chair.

The following papers were then read and discussed:

"Concrete for Maritime Structures," by Chandler Davis, was, in the absence of the author, read by Ernest McCullough.

"Application of Concrete in Barge Canal Work," R. S. Greenman.

"Results of Experiments on the Effect of Sea Water on the Tensile Strength of Various Mixtures of Cement and Sand," Cloyd M. Chapman.

"Preservation of Piles and Timber with Concrete where Exposed to Sea Water," C. C. Horton. This paper was, in the absence of the author, read by the President.

"The Essential Qualities and the Application of Concrete to Timber Structures in Sea Water for the Purpose of Increasing their Permanency," by Ralph Barker, read by title.

The President then announced the appointment by the Elective Members of the Executive Board, of the Chairmen of the following Sectional Committees, who will also be Vice-Presidents and Members of the Executive Board of the Association:

Cement Products and Building Blocks, W. P. Anderson, Chairman.

Exhibition, H. S. Doyle, Chairman.

Fireproofing, R. P. Miller, Chairman.

Insurance, W. H. Ham, Chairman.

Reinforced Concrete and Building Laws, Alfred E. Lindau, Chairman.

Roadways, Sidewalks and Floors, C. W. Boynton, Chairman.

Treatment of Concrete Surfaces, L. C. Wason, Chairman.

The President announced the appointment by the Elective Members of the Executive Board, of Henry C. Turner as Treasurer.

The Committee on Resolutions, Ernest McCullough, Chairman, then reported as follows:

WHEREAS, A general interest in cement and concrete construction has been aroused; and

WHEREAS, The rapidly increasing prices of other building materials have rendered the use of concrete a matter of necessity and a working knowledge of its advantages very desirable; and

WHEREAS, The present short courses on agriculture and like subjects at many state institutions have proven their usefulness and value; therefore, be it

Resolved, That it is the earnest desire of the National Association of Cement Users that a similar course of instruction for cement and concrete be introduced into the schedule of courses of the various state educational institutions, to consist of both lectures and practical instruction and to be planned with two purposes in view:

First. That those taking the course may gain a general knowledge of the nature and characteristics of cement and concrete and learn some of the advantages of the material and the numerous purposes for which it is adapted.

Second. That they may obtain by lectures and, if possible, by practical instruction, a general knowledge of the relative values of the ingredients in a mixture and the correct method of proportioning, mixing and using concrete.

Resolved further, That the President of this Association appoint a committee to communicate or confer with the authorities of the various state institutions regarding this subject, setting before them the advan-

tages of such a course as above described, and urging strongly its adoption and its introduction into the list of courses now available.

This resolution was unanimously adopted.

Resolved, That the thanks of the Association be and are hereby tendered to the officials and other citizens of the city of Chicago for their hearty welcome, recognition of this Association and co-operation in making this, the Sixth Annual Convention, a notable event in the annals of the National Association of Cement Users.

Resolved, That the thanks of this Association be and are hereby tendered to the members who have aided by the presentation of papers, the members of the committees, the local and technical press of the United States for their co-operation and aid in furthering the interests of this Association.

WHEREAS, This Association is convinced that the work of the Structural Materials Testing Laboratories of the United States Geological Survey, Pittsburg, Pa., has been of great benefit to the building industry of the United States and the results published and to be published will be of permanent benefit, not alone to the United States, but to the whole world, thus laying all civilization under obligation to this country and its progressive inhabitants; Therefore, be it

Resolved, That this Association as a body, shall petition the Congress of the United States to provide an adequate appropriation for the purpose of continuing the work of the laboratories during the coming fiscal year.

Resolved, That the thanks of this Association be and are hereby tendered to the officers of the organization and to their capable helpers to whom this Association acknowledges a debt of gratitude for their faithful co-operative work which has borne fruit in the present high standing of this Association. To its able President, Mr. Richard L. Humphrey, this Association feels especial thanks and praise are due for his unceasing and effectual work in its behalf; and be it further

Resolved, That it is the sense of this Association that insofar as the funds of the Association will permit, our President be granted an honorarium as a more substantial recognition of the esteem in which his services are held.

The above resolutions were unanimously adopted, being approved as presented.

On motion duly seconded and approved, the Secretary was instructed to obtain information concerning the bulletins of the United States Geological Survey and in the next circular of the Association to advise the members how to secure copies of the bulletins.

The President thereupon declared the Convention adjourned *sine die.*

NATIONAL ASSOCIATION OF CEMENT USERS.

PROCEEDINGS

OF THE

SIXTH CONVENTION

This Association is not responsible, as a body, for the statements and opinions advanced in its publications.

THE USE OF CONCRETE IN EUROPE.

ANNUAL ADDRESS BY THE PRESIDENT,
RICHARD L. HUMPHREY.*

In the rapid development of the use of concrete in this country, there is a tendency to lose sight of the work of other countries, and it might, therefore, be of interest to indicate the essential differences, the methods employed and the points of excellency in the results obtained. It has been my good fortune to inspect many of the important concrete structures in this country and, during the last four months of the past year, to visit the principal cities of Europe, where, under the guidance of representatives of the various concrete associations and of companies engaged in concrete construction, typical examples of the best work have been inspected. It has, of course, not been possible to see all work of importance, but a sufficient number of structures both in this country and in Europe have been visited to obtain such knowledge of the prevailing conditions as to permit of an intelligent discussion of the subject.

It would seem that the conditions affecting the use of con-

* Consulting Engineer, Philadelphia, Pa.

crete and reinforced concrete are the same the world over. The same problems that confront us here are present on the other side of the ocean. Certain striking differences in the design of structures result from economic conditions as affected by the cost

FIG. 1.—METHOD OF SCAFFOLDING IN EUROPE.

of labor and materials, as will be subsequently pointed out, while the presence of a large number of skilled laborers and mechanics contributes no little to the success of concrete construction in Europe.

In but few respects are the foreign constructors in advance of this country. The most striking instance is in the artistic treatment of the material, which results in many pleasing structures. It would seem that they had also acquired the ability of treating concrete as a plastic material and applying to it an adequate knowledge of the laws of mechanics of materials, together with a rational use of the laws of design. The result is graceful, well-balanced structures, in contrast to some of our cumbersome, ill-designed structures, distinctly lacking in archi-

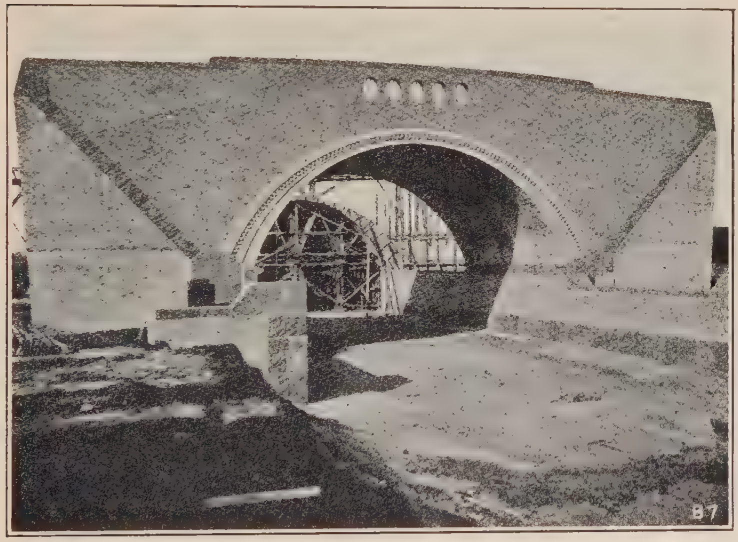

FIG. 2.—RAILROAD BRIDGE, MÜHLHEIM, GERMANY.

tectural effect. The American constructor, either by reason of a lack of knowledge of the properties of concrete and reinforced concrete, or of the laws of design, has in many cases resorted to an excessive use of materials, often decreasing the factor of safety in his efforts to increase it.

This may, perhaps, be explained on the grounds of conservatism, since the use of reinforced concrete in building construction is of recent application, and the scientific investigation of its properties has, for the most part, dealt only with elementary phases of the subject. Much work has yet to be done in the field

of investigation before our theories as to the laws pertaining to reinforced concrete construction can be classed as more than tentative deductions from the elementary data now available. As the result of a visit to the principal laboratories of Europe, it appears that a great deal more research work in concrete has been done in Europe than in this country. It is possible that, as a result of this data, the foreign constructor has acquired more confidence in the use of concrete, which accounts for many applications which appear daring.

Economic considerations, as previously stated, are responsible in part for the graceful appearance of many of the structures.

FIG. 3.—RAILROAD BRIDGE, COLOGNE, GERMANY.

For, by reason of the higher cost of materials as compared with the labor, the designer strives to save all material not necessary for the strength of the structure, and thereby improves its appearance.

In the matter of consistency of the concrete there is an astonishingly wide range of practice. In this country the pendulum has swung from a very dry mixture requiring much ramming to compact it, to a very wet mixture that cannot be rammed. Fortunately, the pendulum is now reaching a middle position, and it is good practice in this country to use a medium consistency that will readily flow, without separation of the aggregates, into all parts of the forms and around the reinforcement through the medium of a slicing tamper.

The practice in Europe covers all conditions of consistency. In Germany the concrete is quite stiff and receives a great deal of tamping; in France it is used so very wet as to require no tamping. In the other countries the concrete is either quite wet or very stiff. None of them appear to have reached the practice of using a concrete of viscous consistency, or one in which there is a maximum of coherency. Such a consistency, in my judgment, is the proper one, and can only be attained through the use of

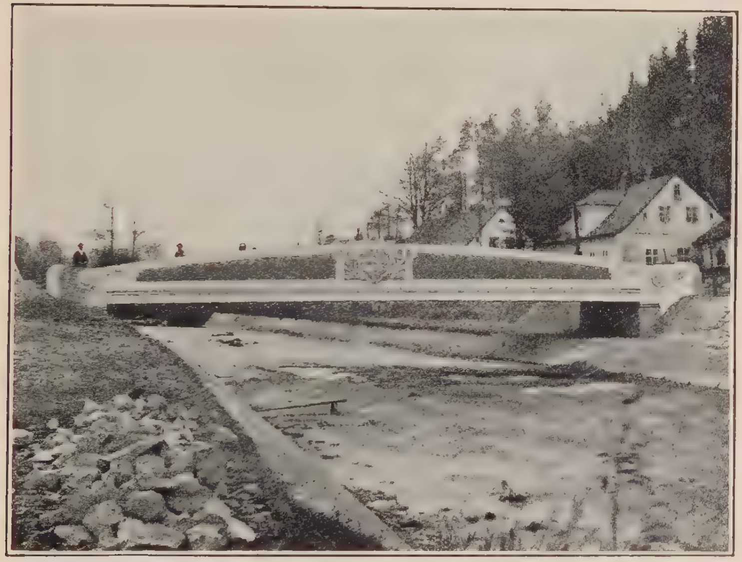

FIG. 4.—FRANZENS BRIDGE, BUCHELSDORF, AUSTRIA.

small, well-graded aggregates and thorough mixing by machinery, using a minimum percentage of water. This consistency will insure great homogeneity and maximum density, will facilitate filling of the forms, and, therefore, result in better finished work. Concrete of this consistency also hardens more rapidly because of the greater density and the minimum percentage of water used, thus permitting the forms to be removed more quickly. Where surface finishes are desired, the finer aggregates produce a surface more readily worked.

In the handling of cement mortar and concrete, the German

laborer seems to possess a better appreciation of the material, for, while using a very dry mixture, he works it into a consistency which produces surfaces showing a minimum amount of hair cracks and crazing. The satisfactory condition of the plastered surfaces of the buildings in Europe is due largely to the skill of the workmen. By reason of the poor quality of the building brick available it is the almost universal practice to plaster the surfaces with a Portland cement mortar in which is used a small quantity of lime paste. For this purpose the rough

FIG. 5.—BRIDGE OVER AAR, STRASSBURG, GERMANY.

bricks are laid with large joints only partly filled with mortar; the plaster is worked into this joint and of a thickness just sufficient to coat the surface of the brick. An examination of many plastered surfaces in various foreign countries did not reveal any that showed the objectionable hair and shrinkage cracks that are so general in this country, particularly in our northern climates.

The cheapness of labor in Europe permits practices uneconomical in this country. The limitation in the height of buildings, generally to five stories, has prevented the development of methods for handling materials, which becomes a problem in the

erection of buildings of many stories. As a result, it is in Europe a common practice to carry the mortar or bricks in tubs, on the head, up inclined runways, in many instances the work being performed by women. In only one instance did I see an elevator used for this purpose, and this was in connection with the erection of an addition to the Telephone Exchange Building in Warsaw. This building consisted of brick bearing walls, with reinforced concrete walls and columns, and was fifteen stories high, being one of the highest buildings in Europe. This fact is

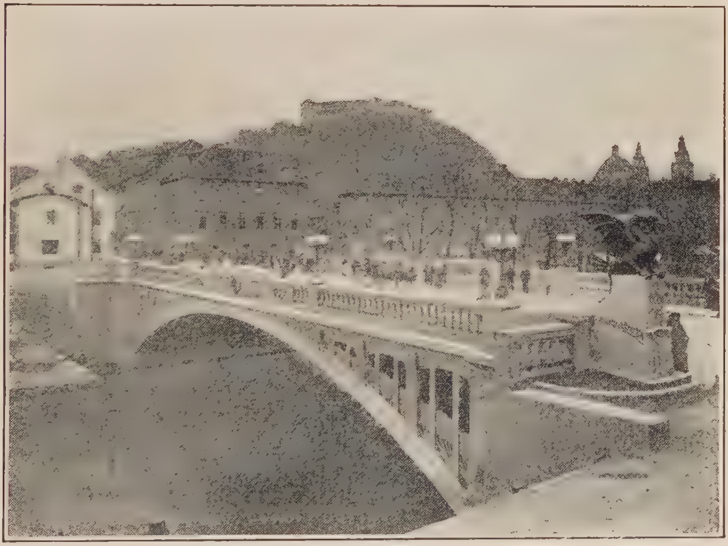

FIG. 6.—KAISER FRANZ JOSEPH BRIDGE, LAIBACH, AUSTRIA.

remarkable because of the prevailing limitation of height, and, further, because this unusually tall structure was of reinforced concrete. An interesting feature in the scaffolding is the general use of round timbers for the framing and the tying of these together, instead of nailing. This type of framing can be used many times and seems to be preferable to the square timbers so common in this country. It would seem that, in view of the growing scarcity of timber and the cost of scaffolding, some similar methods looking to prolong the life of such material could

be very profitably applied in America. The view given in Fig. 1 shows the characteristic method of scaffolding in vogue throughout Europe, and attention is called to the tying of the round timbers forming the framing, and to the side planking along the runways, which prevents material from dropping into the street.

In Europe, as in this country, one of the earliest uses of concrete was for sidewalks, which are quite as general as they

FIG. 7.—RETAINING WALL ALONG LINE STATES RAILWAY, SALZBURG, AUSTRIA.

are in America. The use of concrete for massive work, such as abutments, piers and retaining walls, is also quite common. In the latter, however, reinforced concrete particularly is being used, with a resulting economy over massive construction. In construction of bridges the earlier designs were, as is the case in this country, massive in character, but as the designer acquired confidence, the structures have become more graceful until to-day, light, graceful and pleasing structures are the rule. However, even in massive bridges, the artistic spirit prevails. The paneling of the soffit of the arch, the presence of a beading along the

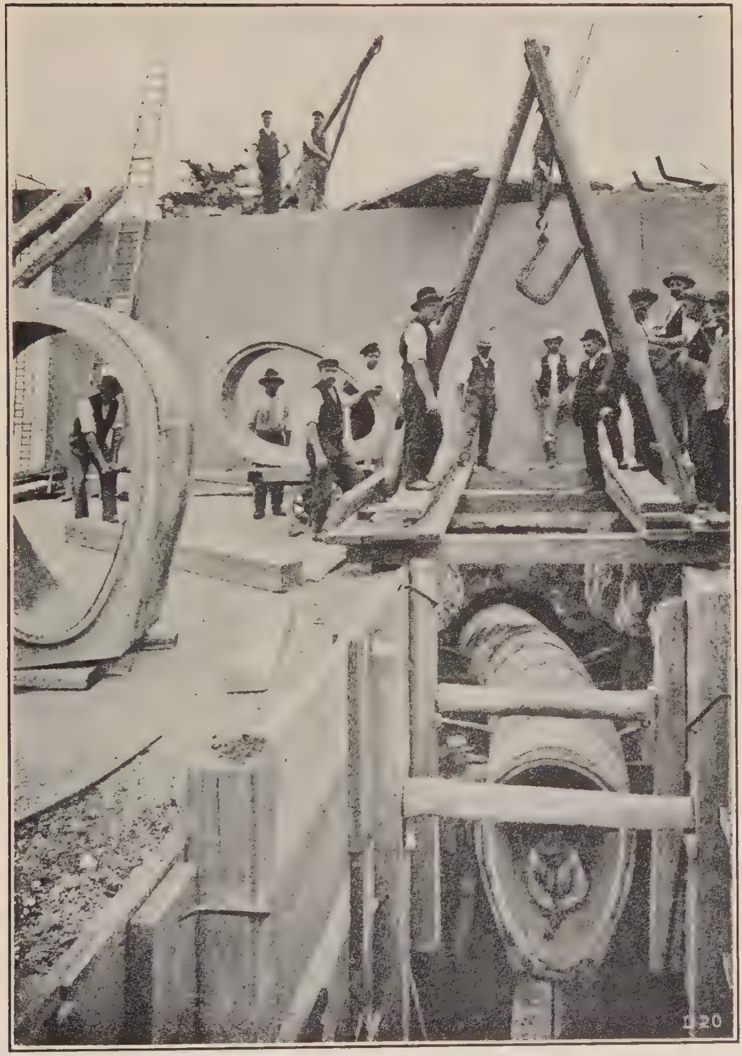

FIG. 8.—CEMENT PIPE BEING LAID IN HAMBURGER STREET, DRESDEN, GERMANY.

intrados, and a treatment of the surface so as to produce uniformity in texture, as indicated in the view of the railroad bridge (Fig. 2), are used with pleasing results. The deep horizontal joint at regular intervals, serving as a break for each day's work, is also utilized to advantage (Fig. 3). The wide use of concrete in bridge construction in Europe is due largely to the cheapness of material, facility of construction, and the economy in maintenance.

Prof. F. Schule, chairman of the commission in charge of

FIG. 9.—CONCRETE PAVEMENT 3 YEARS OLD, ROCKGASSE, VIENNA, AUSTRIA.

the erection of a bridge of large span at Luzerne, Switzerland, stated that competitive bids were received for steel and reinforced concrete, and that the bridge would probably be constructed of reinforced concrete because of the lower cost. Its cheapness in construction, together with the adaptability for obtaining pleasing structures, has made concrete one of the most popular materials of construction for bridge work. Because of these advantages, and the fact that there is practically no maintenance required, it is preferred even where the cost may be a trifle greater than for

other forms of construction. In addition to this, concrete increases in strength with age, and the structure itself becomes more pleasing under the influence of the weather, just as the weather-stained stone bridge is much more attractive than it was immediately after its completion.

It is the practice in Europe to ornament bridges much more elaborately than here, and even small, unimportant structures are given as much attention as the more important ones. One fre-

FIG 10.—CONCRETE PAVEMENT UNDER CONSTRUCTION IN HASNER STREET, VIENNA, AUSTRIA.

quently sees statuary at the approaches, and a well-designed ornamentation which adds materially to the beauty of the structure. A good illustration of the attention given to unimportant bridges is that of the Franzens Bridge (Fig. 4), in which the paneling and the ornamentation at the ends should be noted. In the bridge over the Aar (Fig. 5), the scheme of ornamentation is much more elaborate, with proportionately pleasing results. The possibilities of concrete for bridge construction, both as regards permanency and ornamental qualities, is illustrated in the

Kaiser Franz Joseph Bridge, shown in Fig. 6. The bronze statuary at the approaches and the ornamentation of the main portions of the bridge, which is of graceful design, show the possibilities of the material. This bridge is of 33 meters (108.27 feet) span and 15 meters (49.22 feet) wide.

In this country there are some notable instances of ornamental bridges of this character, among which may be mentioned the Connecticut Avenue Bridge, over Rock Creek, Washington,

FIG. 11.—CONCRETE FILTER BEDS, BERLIN WATER SUPPLY, LICHTENBERG, GERMANY.

D. C., with its imposing lions of concrete at the approaches, and the unusual color effects obtained through the use of crushed granite for the concrete in spandrel walls, producing a light blue-gray color, and of Potomac gravel in the arch rings, piers and abutments, producing a buff color. The Walnut Lane Bridge,* over the Wissahickon Creek in Fairmount Park, Philadelphia, Pa., one of the largest spans of concrete in the world, is another excellent example of the artistic use of concrete. This bridge was constructed of concrete because the cost was lower than for any

*A reproduction of this bridge in color is given in the *Proceedings*, Vol. V, p. 173.

other form of construction. This bridge serves also as an example of the graceful effects which can be obtained through the economical use of concrete, and it is fair to state that the bridge itself would not present such a beautiful appearance if the spandrel arches had been cast solid.

It should be noted, however, that while there are a number of beautifully designed bridges in this country, in Europe there are many such, which fact may be explained as the result of the high development of the artistic sense in the older countries of

FIG. 12.—REINFORCED CONCRETE TRAINSHED, NUREMBERG, GERMANY.

Europe. It is this artistic spirit that makes it essential to finish a structure, and this leads to the ornamentation of even such structures as retaining walls, as illustrated by that along the lines of the State Railway in Salzberg, Austria (Fig. 7). The ornamental caps that surmount the walls at the street intersections, bearing the imperial arms, the water fountain in one of the bays, and other ornamental features, render attractive what would otherwise be an unsightly wall.

It is this treatment of structures of concrete so as to render them more pleasing to the eye, especially those structures whose

chief function is utility rather than ornamentality, that constitutes one of the essential differences between the work in America and Europe. Some attempts have been made in this country to render the surface of walls, abutments and similar structures more

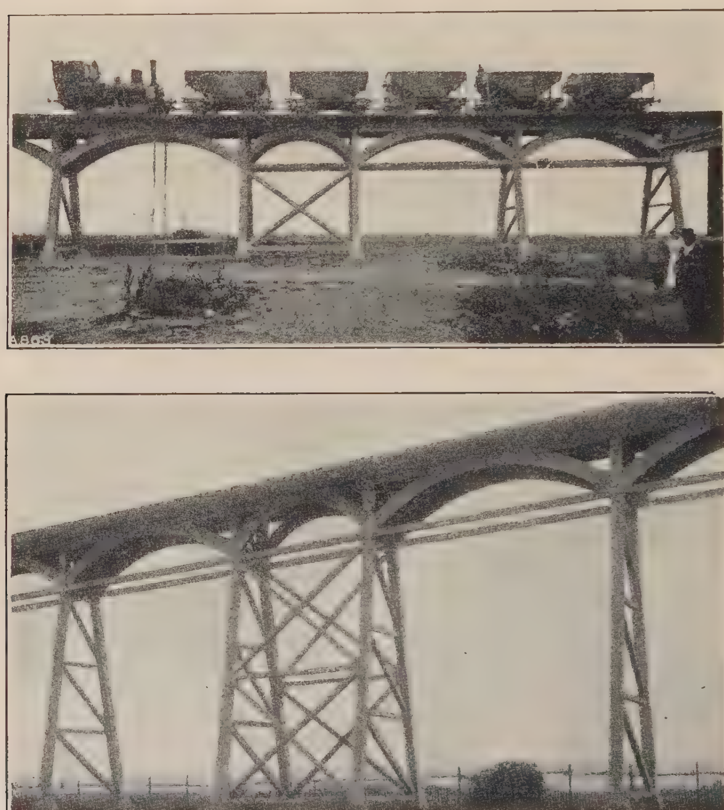

FIG. 13.—REINFORCED CONCRETE TRESTLE, MUNICIPAL GAS WORKS, COPENHAGEN, DENMARK.

pleasing, among which the process of removing the marks of construction through the scrubbed surfaces used in connection with the construction of bridges and other concrete structures in Philadelphia may be cited.

Concrete is quite generally used for sewers in foreign coun-

tries, where it is the practice to line the invert with stone, vitrified brick or tile. There are in use many concrete sewer pipes, both egg-shaped and circular in form, and are, in general, cheaper than brick and other clay tile. One of the best plants for the manufacture of cement pipe visited was that of Dyckerhoff & Widman, located in Amöneburg, near Biebrich, on the Rhine. These pipes have a density so great that they will not readily absorb water, and the pipe rings when struck with a

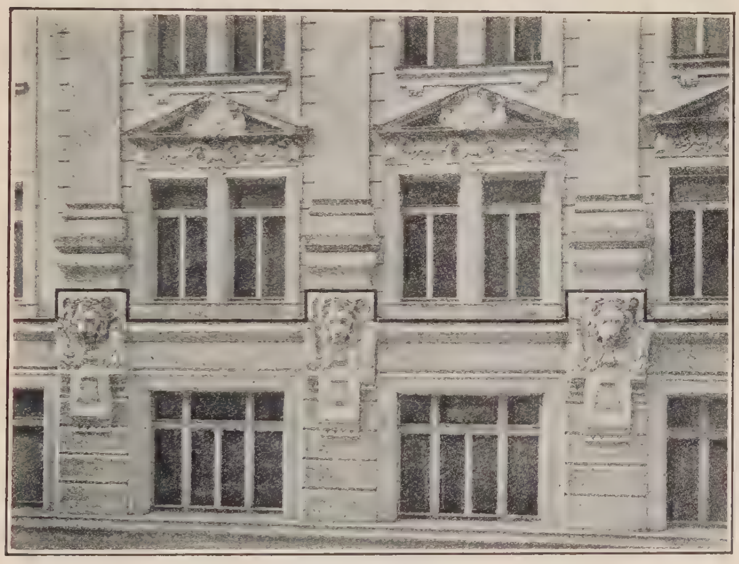

FIG. 14.—FACADE OF HOUSE, VIENNA, AUSTRIA.

hammer. A fairly dry mixture was used and the pipes were molded under heavy pressure, so applied as to rub the materials into position.

A plant in Sweden, near Mälmo, also produces, in a similar manner, pipe of equally good quality. The careful selection and grading of the aggregates, thorough mixing with a minimum percentage of water and molding under high pressure seem to be the secret in the successful production of pipe of this character. Cement pipe made by this process was exhibited in the Louisiana Purchase Exhibition, in St. Louis, and were by far

the best that had heretofore appeared in this country. These pipes were manufactured in Europe and shipped to St. Louis. That they were not damaged by this transportation is evidence

FIG. 15.—FACADE OF HOUSE, VIENNA, AUSTRIA.

of their good quality. The contrast between the quality of this pipe and the quality of most pipe produced in this country is so great that it behooves us to exert our best efforts to secure pipe

of better quality, for, by so doing, many of the troubles now confronting the pipe manufacturers will be eliminated. The quality of this pipe is also due to the care exercised in curing and aging; they are rarely shipped for use before sixty days, and generally not until ninety days, after molding.

Attention is directed to the egg-shaped sewer in Hamburger Street, Dresden (Fig. 8), which serves to show the character of the joints and the method of handling. In many parts of Europe may be found concrete sewers that have been in constant use

FIG. 16.—ENTRANCE, CITY WATER WORKS, UNNA, GERMANY.

for more than twenty-five years. I examined a cement pipe in Vienna, more than twenty-six years old, which was in excellent condition. Under conditions of heavy scour it seems to be the common practice to use vitrified tile for the smaller sewers, and to pave the invert of large sewers with vitrified brick or granite block.

In many cities the laws either prescribe against or limit the percentage of acid or alkali allowable in the waste water of manufacturing plants. Experiments were in progress in a number of places for the purpose of determining the effect of a tar

coating as a preservative for cement pipe against the action of alkali and acid. These experiments had not proceeded far enough to permit conclusions to be drawn. The use of cement pipe seems to be more general in smaller towns, where it answers the purpose admirably. I did not see any of the drain cement tile now in use in this country, and am not, therefore, in a position to make any statement as to their quality or durability.

While concrete sidewalks is one of the earliest uses of

FIG. 17.—REINFORCED CONCRETE ENTRANCE TO SHAFT, WATER WORKS AT BEYREUTH, GERMANY.

cement, its use in both Europe and America for roadways is in a similar state of development. There seems to be a prejudice to the use of concrete for this purpose which operates against the construction of experimental pavements, and this has prevented the attainment of data relative to its adaptability for the purpose. There are, however, some examples of concrete roadways, notably in Vienna, where Leopold Trinka, chief of the Street Department, has been conducting experiments for a number of years. While concrete is used as a base for all street pavements in Vienna, there are, in addition, several streets in

which the entire pavement is of concrete. In Fig. 9 is shown the pavement of the Rockgasse near the Börse. This pavement is three years old and in excellent condition, there being only a slight wearing at the joints, none in the gutter and little on the surface. The street is not subject to excessively heavy traffic, but there is, however, sufficiently heavy traffic to test the wearability of the pavement. The concrete roadway in process of construction in Hasner Street (Fig. 10) was also inspected. This pavement is 75 meters (24.61 feet) wide, curb to curb, and has

FIG. 18.—REINFORCED CONCRETE FACTORY BUILDING, CARL ZEISS, JENA, GERMANY.

2.5 per cent. crown. It is in two parts, viz. the base is 15 cm. (5.91 inches), and the wearing surface 5 cm. (1.97 inches) thick. The concrete for the base was composed of one part Portland cement to three parts sand to five parts gravel, passing a 4-cm. (1.57-inch) ring, while the wearing surface was composed of one part Portland cement, two parts sand and four parts gravel. The sub-base was carefully prepared by rolling and then thoroughly wetted, and on this the base was laid, the consistency of the concrete being rather wet. The top surface was placed afterward and given a float finish. Joints were made every ten meters,

and were formed through the use of tar paper placed in position before the adjacent section was cast. After the wearing surface had hardened somewhat—that is, after the surface water had evaporated—it was covered with sand.

From a conversation with Mr. Trinka, the opinion was formed that he was not in favor of concrete roads where the grades were heavy. His principal objections to concrete roadways was the difficulty of making repairs. As little was known

FIG. 19.—REINFORCED CONCRETE MILL BUILDING, POZSONG, HUNGARY.

about concrete roads, and as they were still experimenting with them in Vienna, he was of the opinion that it was impossible to obtain a good concrete roadway without expansion joints, and if the joints were not formed during construction, cracks would develop afterward. He also believed that the thicker the concrete, the more satisfactory would be the roadway.

Many of the cities make use of concrete pavements for alleyways and smaller streets where the traffic is not heavy, and a number of the cities have in contemplation the laying of experimental roadways. After these experiments are completed it will

probably be found possible to lay concrete roadways that will answer the requirements and prove more economical as regards first cost and maintenance than many of the forms of pavements now in use.

In Europe, as in America, reinforced concrete, because of its flexible qualities, is considered an admirable material for the construction of filter beds (Fig. 11), and other structures required for water supply and sewage disposal. A number of such works

FIG. 20.—REINFORCED CONCRETE FACTORY, PRAGUE, AUSTRIA.

were visited, and mention is particularly made of the controlling works of the sewage-disposal system for the city of Dresden. These are entirely of concrete, and the work was so well done that no patching or touching up was necessary after the removal of the forms, the smoothness of the surface and uniformity of the color being exceptionally good. The concrete was thoroughly mixed, was of a stiff consistency and received considerable tamping. The form work was especially good, and this, together with careful workmanship was responsible for the quality of the work.

In Germany there seems to be a general tendency to use a stiff mixture, and it was stated that this practice was based upon the experiments of Professor Bach, which indicated that the dryer mixtures give the highest results. It is also true that the dryer mixtures do not tend to bring the neat cement to the surface, as is the case with the wetter mixtures, and hence there are less hair cracks.

In reinforced concrete it is, however, difficult to compact stiff concrete around the reinforcement, and the resulting work is

FIG. 21.—REINFORCED CONCRETE HOUSE, VIENNA, AUSTRIA.

unquestionably inferior to that in this country. The stiffness of concrete is, in a measure, offset by the small-sized aggregate used, which facilitates the compacting. I have seen concrete so vigorously tamped in position in a floor panel as to cause vibration of the centering. This floor had a span of about 25 feet, the slab was about 7 inches thick. It is possible that the use of a stiff mortar in plastering, where the surface is thoroughly clean and wetted before it is applied, produces a much more uniform surface, both as regards the texture and the color. It is, however, a fact that the wetter the mixture, the working,

which it must necessarily receive, tends to bring the more soluble and softer materials to the surface, and thereby increases the tendency to checking and hair-cracking.

Large and increasing quantities of concrete are being used in railroad construction. This is due almost wholly to the fact that concrete is the most economical material to use. Where materials are more expensive than the labor, more attention is necessarily given to the economy in their use, and, as a result,

FIG. 22.—DINING ROOM, REINFORCED CONCRETE BUILDING, ASYLUM IN FELDSBERG, AUSTRIA.

forms are more carefully prepared and the concrete more carefully placed. As a result, when the forms are removed little work is required in finishing the structure. The train shed of the Hauptbahnhof, in Nuremburg (Fig. 12), is an illustration of the care taken in the construction of the forms, which results in such perfect structures.

The reinforced concrete trestles (Fig. 13) erected at the municipal gas works, Copenhagen, Denmark, illustrate a tendency toward the use of reinforced concrete as a substitute for steel for

this class of work. This practice has been condemned by many prominent engineers in this country, and there are but one or two notable instances, among which may be mentioned the viaduct near Louisville, Ky. There does not, however, appear to be any valid objection to such construction if properly designed in accordance with the laws of mechanics of materials, and concrete serves the purpose just as well as any other structural material and, in addition, has the distinctive advantage of being more durable, economical, and requiring a less cost of maintenance.

FIG. 23.—REINFORCED CONCRETE HOUSE, DRESDEN, GERMANY.

It is evident that the skill and care of the workmen are responsible in a large degree for the pleasing results obtained in the use of cement for the exterior finish of buildings. Much of this ornamental work lacks the pressed-metal effect which characterizes the appearance of much of the cast-stone work in this country, and this is due to the fact that the surface is gone over with tools, thus removing the skin of neat cement, which gives a dead surface. In addition, the architectural treatment is such as to effectively utilize the natural qualities of the material.

These points are exemplified by the facades shown in Figs.

14 and 15, which have very much the appearance of natural stone. In some instances the ornamentation is placed on the concrete surface after the main structure is finished, but generally it is formed at the time the main structure is cast and is afterwards tooled and dressed by the stone mason, thus removing the marks of construction, the film of neat cement, and giving the structures the appearance of natural stone.

Symmetrical structures in which there has been a well-planned scheme of decoration are quite usual; indeed, one rarely

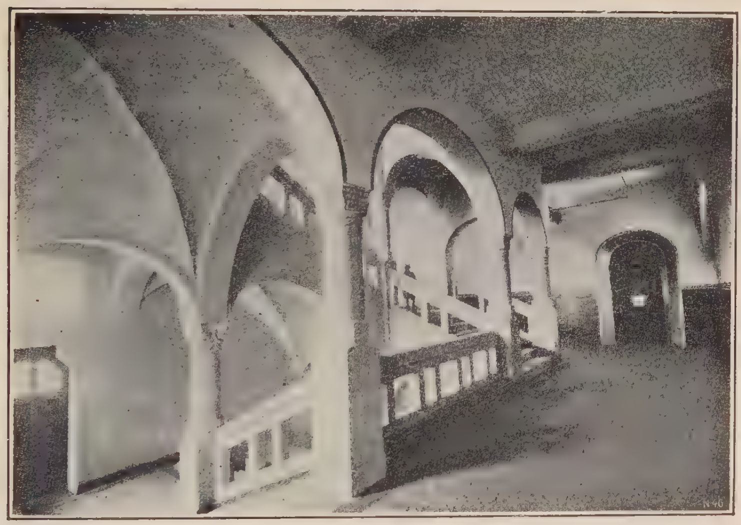

FIG. 24.—REINFORCED CONCRETE STAIRWAY, NORTH SCHOOL, JENA, GERMANY.

sees a structure that does not present a finished appearance. This is a matter in which the American methods may be criticised, especially where the function of the structure is that of utility rather than of ornamentation. Such structures, as a rule, are untouched after the removal of the forms, and, at most, but little work has been put upon them, with the result that they present an unfinished appearance. This condition should not be confused with structures which have purposely unfinished surfaces, as, for example, the grill-room of the Racquet Club in Philadelphia, and the chapel in Mission Inn, Riverside, Cal., in

which the rough concrete is a part of the scheme of decoration. It is the unsightly construction marks and stains, devoid of art and, hence, not pleasing to the eye, to which reference is made, and which are almost wholly the result of carelessness in workmanship, avoidable with practically no additional cost.

The facades shown in Fig. 16 serve to illustrate the care given to structures of minor importance in order to secure a pleasing appearance. The clean lines and fine texture are evident, as is also the case of the structure shown in Fig. 17, where the adaptability of concrete is again apparent. A photograph, as a rule, is a very poor medium for conveying an adequate idea of the appearance of a structure, and often gives the impression that the quality is much finer than it really is, since it tends to eliminate the blemishes. On the other hand, it may not do justice to a very excellent structure, and this particularly is the case where the material is concrete. These expressions of opinion are the result of a close inspection of the structures visited, which were singularly free from such blemishes.

The European architects are wonderfully efficient in the use of concrete without veneering. There are many buildings with exteriors wholly of concrete which are as pleasing architecturally as those obtained by the use of any other material. Factory and mill buildings ordinarily admit of little in the way of architectural treatment, but even these are rendered attractive and pleasing to the eye, as may be seen in Figs. 18 and 19, where the paneling and projecting moldings cast shadows, relieving the plain, flat surface. This gives a life to the structure which makes it attractive, and adds little to the cost.

The treatment of the surfaces, after the forms are removed, by plastering or dressing in various ways with stone cutters' tools, produces a surface of uniform texture and gives a finished appearance to the structure.

The small surface molding and relief work shown in Fig. 20, a factory building in Prague, were accomplished with the original forms, and the finishing applied afterward adds very little to the cost. Much more ornamental surface treatment is shown in the dwelling house (Fig. 21), and serves to illustrate the possibilities of the material. This structure presents a much finer appearance than the brick, stone and similar materials which are used so generally.

FIG. 25.—REINFORCED CONCRETE BUILDING, KING GEORGE GYMNASIUM, DRESDEN, GERMANY.

There were some sixteen reinforced concrete buildings in the course of construction in the city of Hamburg, Germany, many of which had exterior walls of concrete effectively ornamented through the use of cement. In some of these buildings the work was so well performed that it was difficult to tell whether the walls were of stone or concrete.

The treatment of concrete in the interior of buildings is equally effective. Paneling of the ceiling by means of beams, chamfering the edges, the use of filets and moldings, all tend to improve the appearance of the structure. A successful use is also made of plaster, applied to the concrete, in which various designs are worked out in color. These delicate tints, often applied to walls, are not injured by discoloration, which is frequently seen in this class of work in this country. There are a number of processes used for treating the cement surface by which it is rendered inactive. The main element in the success of this work is the fact that walls are allowed to thoroughly dry out before the final ornamentation is applied. In some countries not only is this required by law, but generally the building cannot be occupied at all until after the lapse of at least several months, and in a few cases until one year, after its completion. These requirements are in striking contrast to the conditions prevalent in this country, where a portion of the building can be occupied while the remainder is still in course of erection. From a sanitary point of view this delay in occupancy is admirable.

The dining-room of one of the asylum buildings in Feldesberg (Fig. 22) serves to illustrate the pleasing treatment of the surfaces of a reinforced concrete building with plaster. Another method of treating such construction is illustrated in Fig. 23, in which resort has been made to a partial veneering with wood, this particular building having been awarded the gold medal of the Dresden Exhibition of 1906. In the view of the stairway of the reinforced concrete school building in Jena (Fig. 24) it is evident that a structure can be simply and effectively treated without involving great expense in the construction of the forms. The balustrade without ornamentation, the groined roof of the stairway, and the simple but effective caps of the supporting columns, form altogether a most pleasing construction. The two views

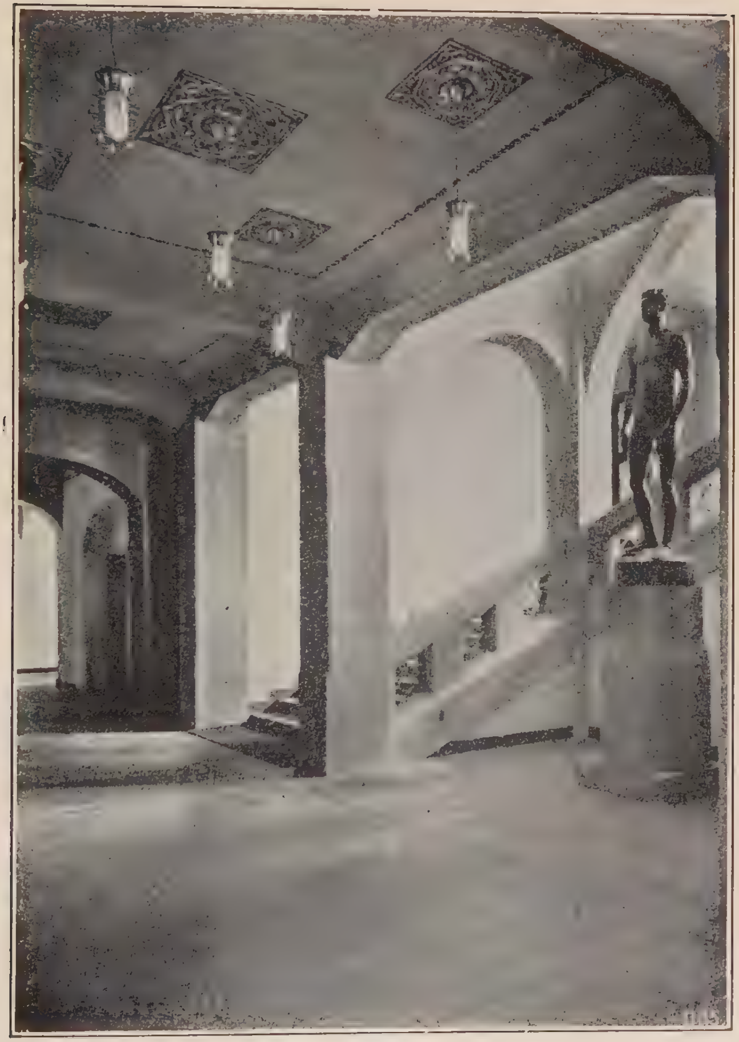

FIG. 26.—REINFORCED CONCRETE BUILDING; KING GEORGE GYMNASIUM, DRESDEN, GERMANY.

(Figs. 25 and 26) of the interior of the gymnasium in Dresden are also illustrative of the high art attained in the interior treatment of structures of reinforced concrete. The concrete in some portions of this building is left untreated, but for the most part the surface has been plastered, and this plaster tinted in various colors. Although completed for some time, I could find no evidences of discoloration, and the entire made a very lasting impression not only as regards the quality of the coloring, but as

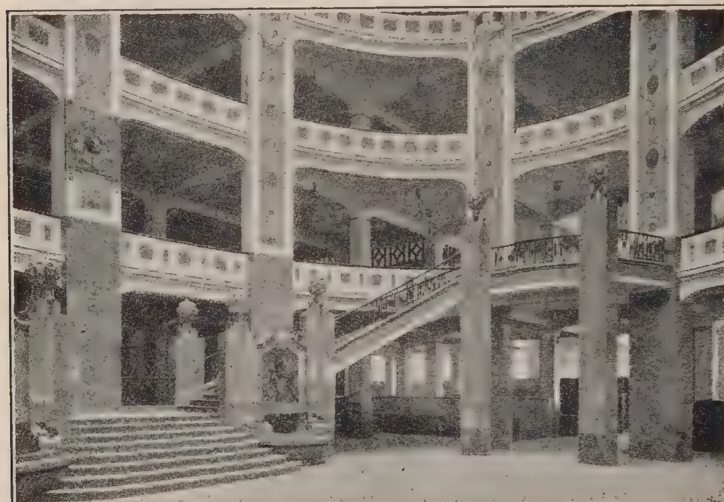

FIG. 27.—CENTRAL ARCADE OF THE REINFORCED CONCRETE BUILDING, THE TIETZ STORES, MUNICH, GERMANY.

regards the details of construction. Attention is directed to the treatment of the columns and paneling of the ceiling, and the extremely simple but effective treatment of the stairway balustrade.

In Paris, I examined a fine structure of reinforced concrete, intended for a music conservatory. In Budapest, Professor Zelinski showed a similar structure designed by himself, which was remarkable for its beauty and the skill exercised in its design. The ornamentation was strikingly good, the acoustic properties were excellent, and the use of the cantilever in the construction of the balcony, thereby eliminating obstructing columns,

was a particularly fine piece of construction. The treatment of the surface in the corridors was simple, and the ornamentation consisted in part of designs worked in mosaic.

In many instances the interior finish for concrete buildings was in imitation of the travertine stone obtained from Italy, and was so well done as to make it impossible to tell whether it was artificial or not. Work of this character has been equally well executed in the new Pennsylvania Railroad Station in New York, where, in the lobby of the station, the lower part is of natural

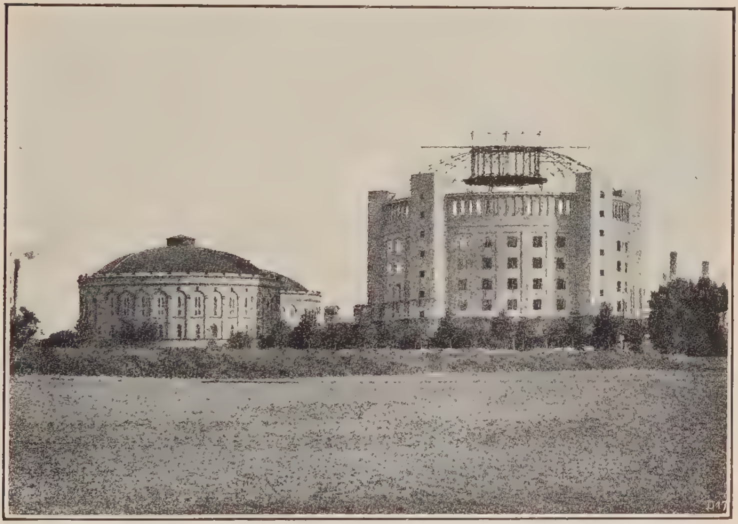

FIG. 28.—REINFORCED CONCRETE WALLS FOR GAS HOLDER, DRESDEN, GERMANY.

travertine stone, while the upper portion is artificial. Even the workmen have difficulty in indicating where the one ends and the other begins.

Light, graceful trusses used for supporting the roofs of buildings are also worthy of notice, and ample evidence is afforded of their stiffness in the attached shafting and other machinery, which produces no appreciable vibration to the structure.

Perhaps one of the most pleasing examples of the decorative art was the treatment of the central arcade of the reinforced concrete building (Fig. 27) of the Tietz stores, in Munich; the

paneling of the ceilings, the detailed construction of the columns and the ornamental work being so apparent that further description is unnecessary.

The spirit of ornamentation is illustrated in the gas holders of the city of Dresden, shown in Fig. 28. In this country,

FIG. 29.—REINFORCED CONCRETE FOUNDATION FOR QUAY WALLS IN HARBOR, NORRESUNDBY, DENMARK.

especially, these are unsightly structures of metal. In this case the walls, of reinforced concrete made to imitate granite, serve as a container for the holder proper, which is of metal. The surfaces of these walls are hammer-dressed, and the metal-covered roof, supported by steel trusses, is painted with a green-tinted paint, giving the appearance of oxidized copper, the whole structure being unusually attractive and pleasing, which is not usual

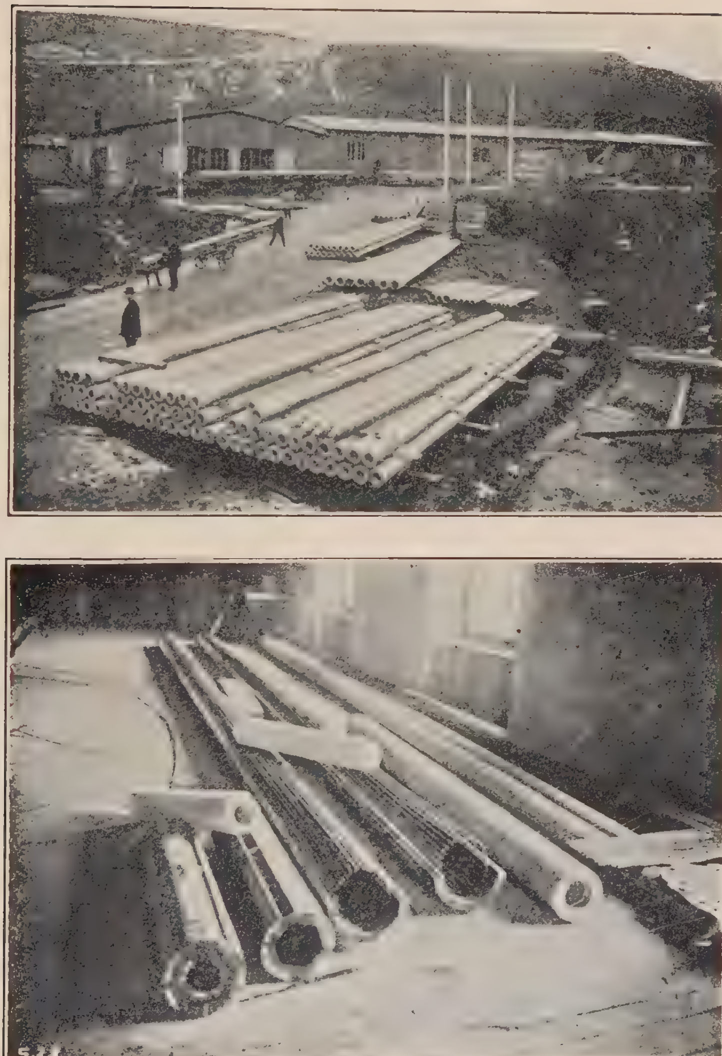

FIG. 30.—HOLLOW REINFORCED POLES, OTTO AND SCHLOSSER'S PLANT, MEISSEN, GERMANY.

in a structure of this character. The view given shows one of the roofs of the holder uncompleted and serves to illustrate the character of the roof construction, the steel work not being incased in concrete. The towers seen contain stairways, also of reinforced concrete. The gray tone of the walls is in splendid contrast with the soft green coloring of the roof.

In the design of reinforced concrete structures, the European engineer seems to have a better appreciation of the laws of design, which shows itself not only in the gracefulness of the structure, but also in the thickness of the concrete itself. A number of concrete water towers were visited, with walls extremely thin, and reference is made to one in Budapest, designed by Professor Zelinski, which was perfectly tight, although there was a considerable head of water. The thin walls had been rendered tight not by waterproofing, but through the intelligent use of metal reinforcement, a practice which is at last beginning to be understood and applied in this country.

In the use of reinforcement for harbor work there was much of interest. The length and manner of driving the concrete piles in the harbor work at Boulogne-sur-Mer was particularly impressive. The piles apparently stood the severe hammering of the pile-drivers without damage. Results similar to this have been achieved in driving the piles in connection with the harbor work at Chester, Pa.

An application of reinforced concrete that is likely to come into greater use is illustrated in Fig. 29. The boxes of reinforced concrete are constructed on shore, launched as shown, towed to a point where they are settled into position by filling with sand, gravel or crushed stone; upon this superstructure the quay wall is then built. This method of construction permits the thorough hardening of the concrete before it is subjected to the action of sea water.

Reinforced concrete telephone and telegraph poles seem to be coming into general use, especially in Holland, Sweden and Denmark, in which countries inspection was made of poles that had been in use for some time. Some types of poles are shown in Figs. 30 and 31, the feature of which is the attempt to lighten them, and thereby save material, through the means of holes spaced regularly as shown. Nearly all of the poles examined

were in excellent condition and seemed to answer the purpose admirably. The strength and permanency of this type of pole

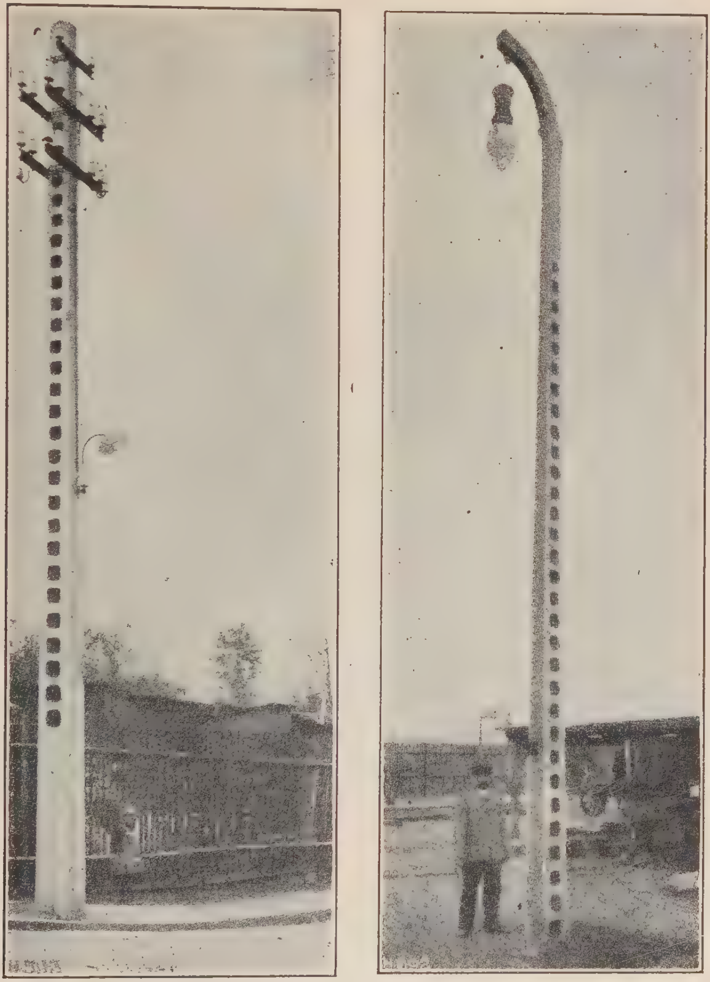

FIG. 31.—REINFORCED CONCRETE LIGHT, TELEPHONE AND TELEGRAPH POLES.

make it preferable to poles of wood or steel, even where the first cost may be somewhat greater.

An interesting use of concrete is the rustic foot bridge shown

in Fig. 32, the entire structure being of concrete with a small amount of metal reinforcement. The floor and railing were cast, using the planks and railing of the previous structure in forming the molds.

Equally interesting is the reinforced concrete fence shown in Fig. 33. The hinges were imbedded in concrete. While these gates are quite heavy and are frequently closed with such vigor as to jar

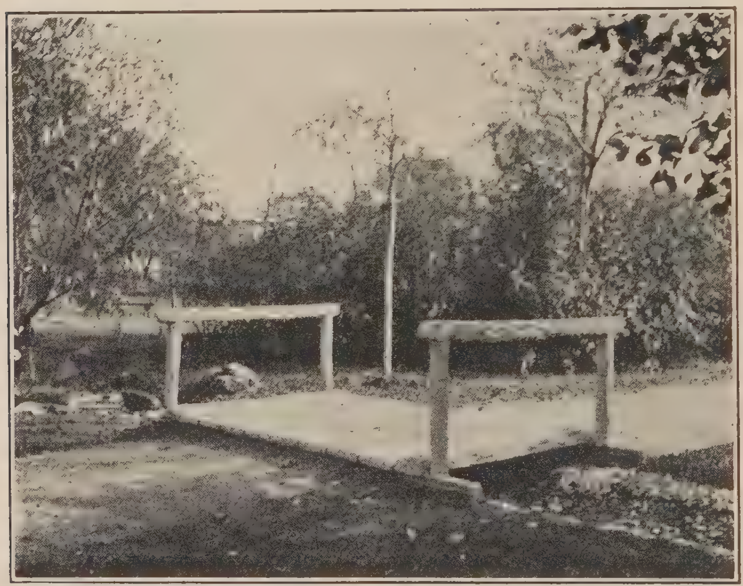

FIG. 32.—FOOT BRIDGE IN PARK, ENTIRELY OF REINFORCED CONCRETE, BUDAPEST, HUNGARY.

the fence, the cracking is not nearly as bad as might be expected. This, however, is a use of concrete for which it is not suited, because of the weight and the consequent shock on the hinges in opening and closing the gates. The fence itself was in excellent condition, and demonstrated the adaptability of concrete for the purpose.

Mention should also be made of the reinforced concrete boat, or barge, inspected at Frankfort-on-the-Main, 42 meters (138 feet) long and 6.5 meters (21.32 feet) wide at the center, and with walls 4 cm. (1.48 inches) thick. The boat was being

repaired at the time because of the unequal distribution of the concrete, due to faulty design, which had caused a serious list. The boat was painted with asphalt and seemed perfectly watertight. It contained a small cabin in the stern, the remainder of the boat being intended for cargo. The same constructors contemplated building another boat 70 meters (229.66 feet) long. Boats of this character are being constructed and successfully used in this country, especially in connection with the construction of the Panama Canal. The success of these boats depends

FIG. 33.—REINFORCED CONCRETE FENCE, BUDAPEST, HUNGARY.

largely on the design, which, if proper, should make them sufficiently stiff and thoroughly watertight. When well designed and built, the first cost is little, if any, greater than when built of wood, while the cost of maintenance is very low and the durability very great. In view of the growing scarcity of timber, it is probable that this type of boat will meet with increasing favor.

In Europe, as in America, concrete is winning its way as a building material because of its intrinsic qualities, which make it superior as regards strength, durability and fire-resistive qualities, and also the most economical.

Many of the problems that are at present receiving consider-

ation in this country are also under consideration in Europe. The investigations of the properties of concrete have been more extensive than those in this country, and the results contain much data of value to the American engineer. Too little reference has been made to the work of the foreign investigator when reporting the results of the investigations in this country.

While reinforced concrete construction had its origin in Europe, and has been in use, therefore, longer than in this country, yet it is surprising that the present extent of this use is no greater. One cause that operates against the development of its use in buildings lies in the restrictive, and in many cases prohibitive, building regulations, which render it impractical either to use the material in the larger cities at all, or with any economy. Hence, its use is almost wholly outside of these cities. The revision of these laws is under consideration in most foreign cities, the purpose of which is to so modify them as to render this class of construction possible. The economic value of the material, coupled with its superior qualities from a sanitary and fire-resistive point of view, is aiding materially in the fight for its proper recognition.

In general, it may be stated that America leads not only in the extent, but also in the diverse uses of concrete and reinforced concrete. It is, however, in the artistic use that Europe excels; the results obtained are in general much more pleasing. When American architects become more familiar with, and confident in the use of, concrete, treating it as a plastic material with an individuality of its own, and not as a substitute for other and, in most cases, inferior materials of construction, we can hope to rival Europe in this field. Many foreign designers also appreciate its properties and possibilities more fully than is the case in America, and more economically designed structures are the result.

Europe is watching America's progress with keen interest, and with good reason, for already we have designed structures of concrete in which full use has been made of its admirable qualities. We are also formulating rules for its use that are being accepted in other countries, and our knowledge of design is so progressing that economical structures are becoming more common. In the very near future we may look to see America lead the world in the artistic and economical use of concrete.

REINFORCED CONCRETE COLUMNS.

By Peter Gillespie.*

In the study of the elastic properties of any material, the stress-strain curve is a very important aid. Straightness on such a curve is evidence that Hooke's law of proportionality of stress to deformation obtains. The steepness of the curve with respect to the axis of strain is the measure of the rigidity of the material—perpendicularity to this axis denoting infinite stiffness and parallelism to the same axis, complete plasticity. The elastic limit is indicated by the point of departure of the curve from the straight line. The true elastic limit is in most instances not definitely marked; but, in the case of soft steel and wrought iron, the position of the so-called apparent elastic limit or yield point need never be mistaken. The return path is plotted by observing simultaneous values of stress and strain under decreasing loads. The intercept, if any, of this path on the axis of strain is the measure of the permanent set. A repetition of the stresses and a replotting will show to what extent, if at all, the properties of the material have altered because of the process of re-stressing.

Since, in the discussion of efficiency and economy in concrete column design, the elastic and other properties of the material to be employed are of vital importance, there is shown by way of illustration (Fig. 1)† the stress-strain curves for two concrete prisms the data for which were obtained from *Tests of Metals* for 1904.

The upper curve is for a 1 : 1 cement and sand mortar with an ultimate crushing strength of 6,940 lbs. per sq. in.; the lower is for a 1 : 2 : 4 cement, sand and gravel mixture, which failed at 1,700 lbs. per sq. in. It will be observed that while the former continues straight up to a stress of 2,500 lbs. per sq. in., the

* Lecturer, Faculty of Applied Science, University of Toronto, Toronto, Canada.

† Acknowledgment is made to the *Engineering Record* for the cuts of Figs. 1, 2, 5, 7, 8, 9, and 10.—Ed.

latter deflects almost from the start. That the former is at the outset almost twice as steep as the latter, will be interpreted as meaning that the modulus of elasticity of the richer concrete is nearly twice as great as that of the poorer. That there would be a permanent set for relatively small stresses in the case of the

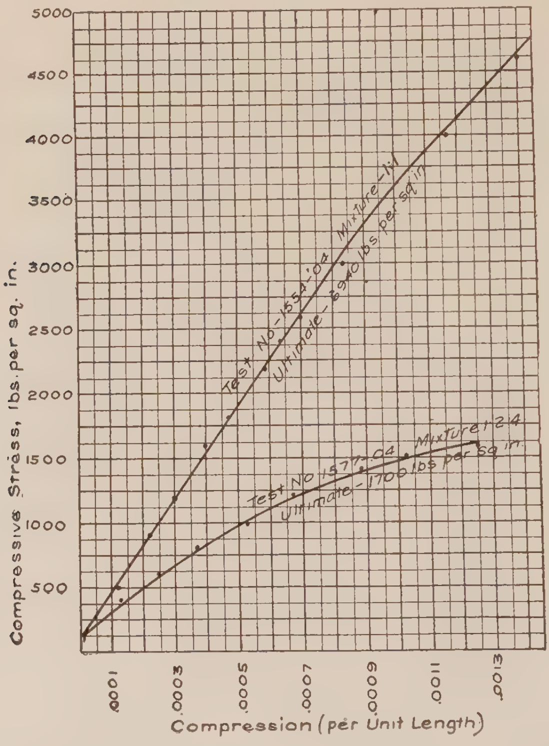

FIG. I.—TYPICAL STRESS-STRAIN CURVE FOR RICH AND LEAN MIXTURE.

latter would be anticipated. As might also be expected, a much closer approach to complete recovery was realized in the other instance after even moderately large stresses.

For the reinforcement of concrete columns, two methods have been adopted, viz.—longitudinal rods and hoops or spirals. Frequently, indeed, the two methods are employed in combination. The former depends for its effectiveness on the fact that when two dissimilar materials deform together, they take stresses

in proportion to their relative rigidities. That is to say, if the steel in the longitudinal reinforcing of a concrete column be ten times as rigid as the surrounding concrete, its stress for a given deformation will be ten times that of the concrete. Experiments conducted on columns of concrete of the grade ordinarily manufactured and reinforced with longitudinal rods show that the stress in the steel, accompanying stress in concrete of such intensity as is commonly specified, are very much lower than good practice will endorse or economy recommend.

Table I gives some data taken from *Tests of Metals* for 1904,

TABLE I.—SIMULTANEOUS STRESSES IN CONCRETE AND STEEL.
Percentage of metal in longitudinals, .97 to 2.09.

Test No.	Mixture.	Average Stress, lbs. per sq. in.	Steel Stress, lbs. per sq. in.	Concrete Stress, lbs. per sq. in.	Steel Stress. / Concrete Stress.	Ultimate Strength, lbs. per sq. in.
1613	1:1:2	600	3,540	556	6.4	2,890
1612	1:2:3	600	6,360	516	12.3	2,010
1582	1:2:4	600	5,040	557	9.0	2,180
1581	1:2:4	600	5,520	549	10.1	1,990
1584	1:2:4	600	4,320	527	8.2	2,830
1579	1:2:4	600	3,780	532	7.1	2,760
1610	1:2:4	600	5,220	532	9.8	1,820
1616	1:2:4	600	9,060	476	19.0	2,095
1608	1:3:6	600	11,100	446	24.9	1,370
1617	1:3:6	600	4,860	516	9.4	2,290
Average	....	....	6,000	530	11.6	....

showing simultaneous values of stress in concrete and in steel longitudinals of compression members having from .97 to 2.09 per cent. of reinforcement. From this table, it is seen that in columns carrying 600 lbs. per sq. in. over the gross area, the average stress in the steel longitudinals was only 6,000 lbs. per sq. in. In structural and bridge work, working stresses at least twice this would not be considered excessive. It is undoubtedly true that metal is sometimes employed in structures for emergency purposes, and ordinarily may sustain stresses which are very small indeed or absent altogether. In the case of concrete columns, this is partly true. To take care of bending stresses due to eccentric loading or to possible inequalities in the con-

crete, longitudinal rods are necessary; still, if the working stresses could be increased somewhat past the limit given in the table, it could be felt that more of the advantages of the use of the metal were being realized, particularly since, even when stressed to the

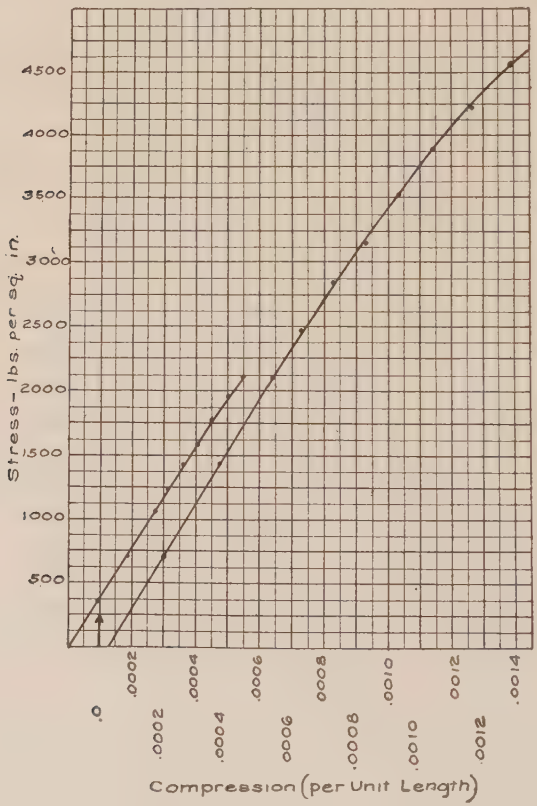

FIG. 2.—STRESS-STRAIN CURVE FOR 1:1 MIXTURE AT 3 MONTHS

maximum which good practice favors, it carries a load in compression at about twice the cost of concrete.

By employing a better grade of concrete, thus permitting the utilization of higher working stresses, a partial remedy is secured. An improvement in quality is, however, accompanied by a marked increase in the elastic modulus as well as in the ulti-

mate strength, as is indicated in Figs. 1 and 2, the latter being a typical curve for a plain 1 : 1 concrete at age of three months, plotted from a test made by the writer. The aggregate was a hard trap rock, with the fine crusher dust screened out, the size of aggregate varying from ¼ to ¾ in. The member was first stressed up to 2,200 lbs. per sq. in. when the load was released. The magnitude of the set is almost insignificant, it being observed that the second curve is plotted from a new origin. The prolonged straightness of the curve is one of its most noticeable features. The increase in stiffness which occurs whenever the quality of the concrete is improved, will mean a reduction in the stiffness ratio for the two materials so that the increase in the steel stress due to the employment of a richer mixture, is not as great as might at first be supposed.

In Table II are given the results of a few compression tests made by the writer on columns of this grade of concrete. The specimens were 6 ins. in diameter and 21 ins. long.

TABLE II.—COMPRESSION TESTS ON SHORT COLUMNS.

Mixture, 1 : 1. Age, 6 months.

Specimen.	Crushing Strength, lbs. per sq. in.
A	4,900
B	5,975
C	5,150
D	6,160
E	4,120
F	5,480
Average	5,300

As the average strength is well over 5,000 lbs. per sq. in., it would seem that a working stress of 1,250 lbs. per sq. in. is not excessive.

To determine the manner in which such material will behave in combination with metal, longitudinally placed, a number of columns were constructed and tested. Fig. 3 shows such a column under test. Nine determinations of the modulus of elasticity for this plain concrete, gave an average value of 3,900,000 lbs. per sq. in. with the smallest value 4 per cent. and the largest 45 per cent. higher than the mean of all. Eight determinations of the elastic modulus in columns reinforced with from

.88 to 4.42 per cent. of steel, gave an average value of 3,600,000 lbs. per sq. in., showing that apparently the concrete is less rigid in the reinforced column than it is in the plain. In the latter case, the smallest value was 13 per cent. less and the greatest 11 per cent. more than the mean of all. Typical stress-strain curves

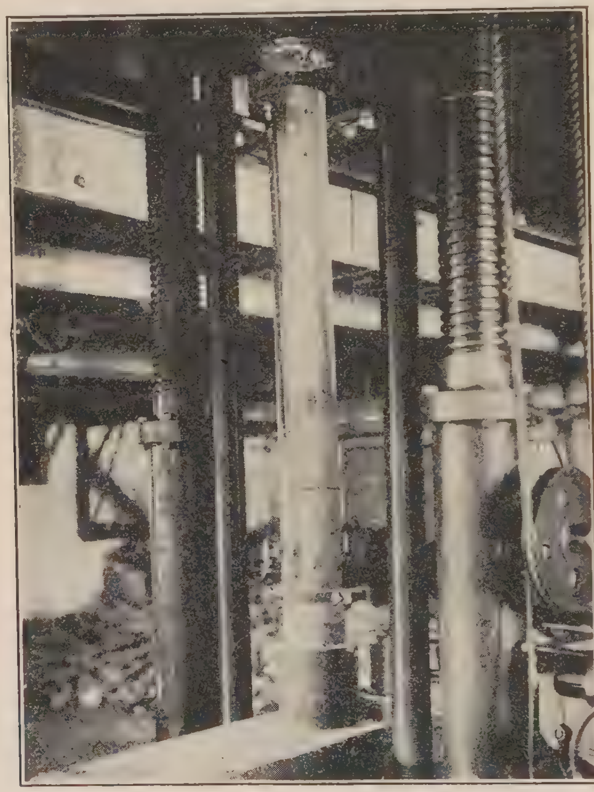

FIG. 3.—COLUMN REINFORCED WITH LONGITUDINAL RODS UNDER TEST.

for these columns are shown in Fig. 4. It will be noticed that the set following the stresses indicated in the first two applications of load, is practically zero. The curve for the reinforcement is drawn in such a way, that the portion of the average or gross stress between it and the curve proper, is the measure of the stress in the concrete. In this way, it is possible to

determine the simultaneous stresses in the two materials, since the metal stress may be found by multiplying the unit deformation by the elastic modulus of that material. This method of graphical segregation is always possible and it will be evident that the reinforcement curve will be steepest where the quantity of metal is greatest. Table III shows in a few other representative cases, the magnitude of the stress in the longitudinal reinforcement accompanying a stress of 1,250 lbs. per sq. in. in the concrete.

On account of the increased working stress in the concrete, the average stress in the metal is substantially greater. The

TABLE III.—SIMULTANEOUS STRESSES IN CONCRETE AND METAL LONGITUDINALS.

Mixture, 1 : 1. Percentage of metal, .88 to 4.42.

Designation.	Stress in Concrete, lbs. per sq. in.	Stress in Metal, lbs. per sq. in.	Metal Stress. / Concrete Stress.
M	1,250	9,300	7.4
J	1,250	9,600	7.7
H	1,250	10,500	8.4
N	1,250	10,500	8.4
Q	1,250	12,000	9.6
R	1,250	10,800	8.6
O	1,250	10,500	8.4
P	1,250	10,500	8.4
Average	1,250	10,400	8.4

attainment of such stresses, rendered possible through the employment of a better grade of concrete, must be considered a step toward the economical use of steel in concrete columns.

Another matter of some consequence is the amount of set taken by the concrete after the stress is relieved. The most satisfactory materials for the purpose of the engineer are those which have for moderate stresses, the power of perfect recovery. Of concrete, as ordinarily manufactured, this can scarcely be said. It will be observed from Table IV, that the average set for the rich concrete after a stress of 2,000 lbs. per sq. in. is approximately half as great as that of the poorer grade after a stress of half the magnitude. The data is taken somewhat at random from the report of the Watertown Arsenal for 1904,

but is believed to be fairly representative of the two grades of material.

The function of hoops in compression members is to resist the lateral expansion which accompanies longitudinal compression due to load. For most materials, there is a more or less constant ratio between the lateral and the longitudinal strain. This is known ordinarily as Poisson's ratio and for most materials of construction is about ⅓ or ¼. Let us assume a concrete column reinforced with hoops and with longitudinal rods. When it is stressed by loading a longitudinal shortening takes place which sets up stresses in both steel and concrete, the ratio between them being the ratio of their relative rigidities. If the hoops were

Table IV.—Showing the Amount of Set in Two Grades of Concrete after the Release of Stresses.

All specimens 12 ins. long.

After 2,000 lbs. per sq. in.			After 1,000 lbs. per sq. in.		
Mixture.	Set in ins.	Ult. Strength, lbs. per sq. in.	Mixture.	Set in ins.	Ult. Strength, lbs. per sq. in.
1 : 1	.0006	6,940	1 : 2 : 4	.0028	1,210
1 : 1	.0013	4,800	1 : 2 : 4	.0020	1,700
1 : 1	.0014	4,360	1 : 2 : 4	.0010	1,480
1 : 1	.0004	6,400	1 : 2 : 3	.0012	1,680
Average	.0009	....	....	.0017	....

absent, a lateral expansion would have taken place which, per unit of diameter would be only a fraction of the afore-mentioned shortening per unit of length. The hoops reduce this to some extent (otherwise they would not serve their purpose), and, consequently, the unit deformation in them must be of even smaller extent. From this it is manifest that hoop stress will be very much less than the compressive stress carried at the same time by the longitudinal rods, and if some misgivings are had as to the wisdom of employing longitudinal metal in columns, certainly greater doubt might be entertained regarding the use of hoops. For while the fabrication of hooped reinforcement is usually more expensive than those of longitudinal rods, the safeguard against bending due to eccentric loads and defective materials locally, is very inadequately afforded.

In the hooped columns, the tests on which are referred to below, a 1 : 1 mixture of small size trap rock and cement was used. The hoops were welded from steel flats and were of two thicknesses, .05 and .12 ins. The quantity of metal relative to the core within the hoops varied from .024 to .057 per cent. No

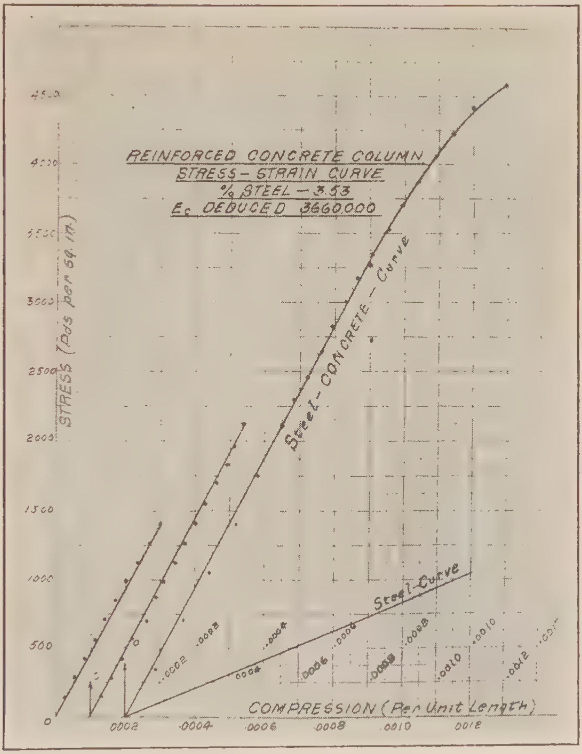

FIG. 4.—CURVE SHOWING BEHAVIOR OF COLUMN 1 : 1 CONCRETE WITH LONGITUDINAL REINFORCEMENT.

longitudinal metal was employed save three strips of thin hoop iron which were employed as spacers for the hoops. Fig. 5 shows the hoop reinforcement assembled. In order to measure the stresses in the hoops, certain of the rings were left exposed, partly or completely, and to these mirror extensometers were attached (see Fig. 6). Longitudinal deformations were measured by means

of compressometers fixed to a gauge length of about 50 ins. The curves in Figs. 7, 8 and 9 afford an opportunity to note the manner in which the steel stress varies with the compressive stress in the concrete. In every case as the concrete was subjected to higher compressive stresses, a tendency manifested itself on the part of the curve to deflect downward. In some cases, the curve becomes parallel with the axis of steel stress.

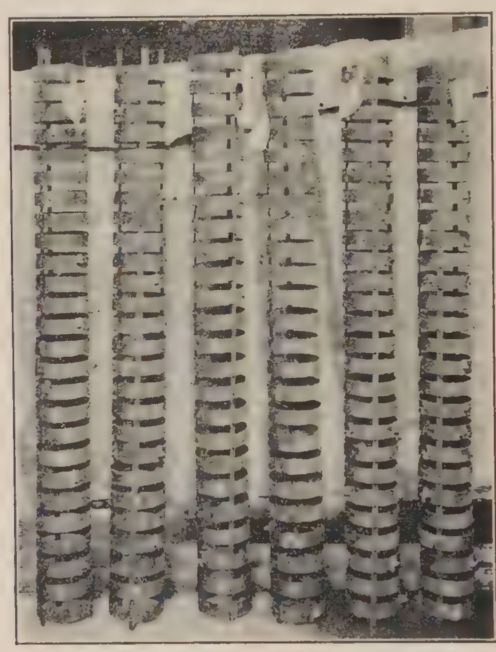

FIG. 5.—HOOPS READY FOR FORMS.

This would indicate that the concrete, under high compressive stresses, had reached a state of partial plasticity within the hoops. The fact that, on release of load after heavy stressing, the extensometers did not usually completely recover, would indicate that this apparent tendency to flow had left the steel in a state of residual tension, since usually the steel stress had not even approached the elastic limit. In Fig. 8 the continued increase in steel stress under a constant load is shown.

From purely theoretical considerations, if the elastic properties of the materials and the quantity of hooping present are known, it is possible to establish a simple relation between the compressive stress in the concrete and the accompanying stress in the hoops. In the evolution of the following equation the stiffness ratio for this material was assumed to be 9. A number of determinations of Poisson's ratio gave ¼ for an average value. For these materials, it can be shown that

$$\frac{f_s}{f_c} = \frac{9}{4 + \frac{9}{2}p}$$

where f_s is stress in hoops, f_c axial compressive stress in the concrete and p is the ratio of metal to concrete within the hoops.

TABLE V.—SIMULTANEOUS STRESSES IN CONCRETE AND METAL HOOPS. Mixture, 1 : 1. Percentage of metal in hoops, 2.4 to 5.7.

Concrete Stress, lbs. per sq. in.	Hoop Stress, lbs. per sq. in.	p	Metal Stress. / Concrete Stress.	State of Hoop.
2,400	5,500	.057	2.28	Partially exposed.
3,000	7,000	.024	2.30	Completely exposed.
1,900	4,300	.057	2.26	Partially exposed.
2,300	5,000	.057	2.18	Partially exposed.
2,000	4,700	.057	2.34	Partially exposed.
3,000	6,000	.057	2.00	Partially exposed.
3,250	4,000	.057	1.23	Completely exposed.
2,600	5,000	.024	1.92	Partially exposed.
2,300	5,000	.027	2.17	Partially exposed.
2,800	5,000	.024	1.77	Completely exposed.
2,750	5,000	.027	1.82	Completely exposed.
Average....	......	....	2.02	

Since p is usually small with respect to the other numbers involved, it follows that the usual changes which p might undergo, do not affect the ratio $\frac{f_s}{f_c}$ in a very conspicuous way. Fig. 10 shows the manner in which this ratio changes, consequent on variation of p. The points plotted adjacent to the curve show to what extent the theoretic investigation agrees with the results of experiment. In Table V are given a few simultaneous values

of hoop stress and compressive stress in concrete. The figures are representative of a somewhat large number of determinations and, broadly speaking, show as is indicated in Figs. 7, 8, 9 and 10, that for the materials employed, the hoop stress is approximately twice that in the concrete.

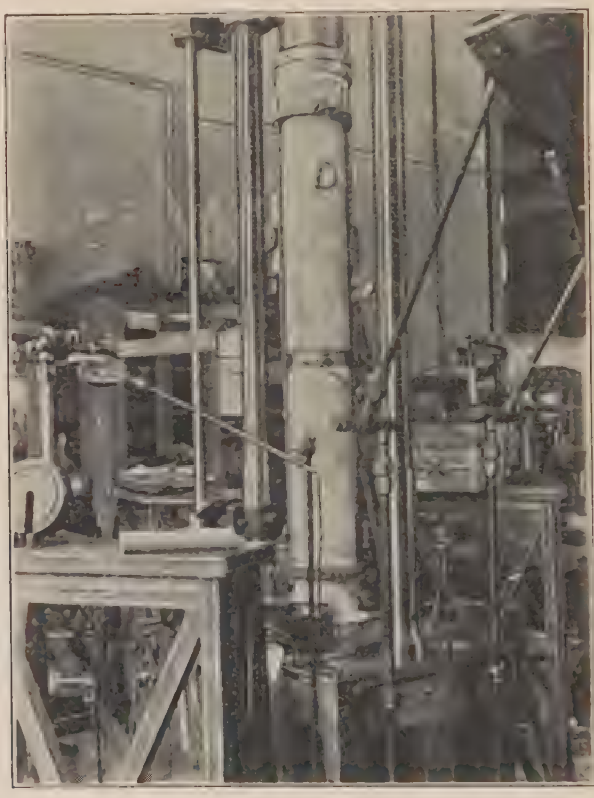

FIG. 6.—A HOOPED COLUMN IN THE TESTING MACHINE.

Tests made by Professor Talbot in 1907 on hooped concrete columns, using a 1:2:4 mixture, showed that the ultimate strength was increased about 570 lbs. per sq. in. for each per cent of hooping employed. Similarly, tests made at the Watertown Arsenal in 1906, show that one per cent. of metal in the

form of hoops increased the strength of the member to the extent of 1,020 lbs. per sq. in. Professor Withey, in 1909, reported that for each per cent. of metal employed in the form of spiral reinforcing, the increase in ultimate strength on an average was 1,320 lbs. per sq. in. for 1:2:4 concrete. From these and other tests which might be cited, a generous allowance for hooping would be 1,000 lbs. per sq. in. gross strength for each per cent. of metal employed. Tests conducted on hooped col-

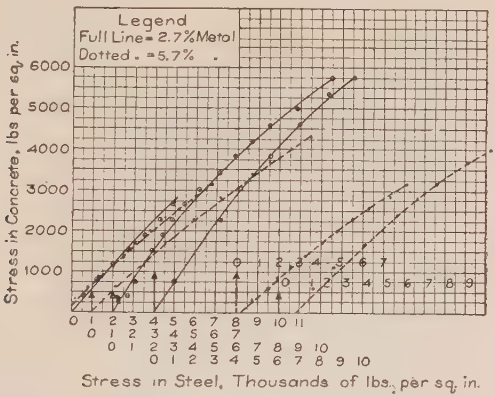

FIG. 7 (DOTTED LINES) AND FIG. 9 (FULL LINES).—CURVES SHOWING RATIO BETWEEN METAL STRESS AND AXIAL COMPRESSIVE STRESS IN 1:1 HOOPED CONCRETE COLUMNS.

umns reinforced also with longitudinal rods indicate that greater efficiency is obtained from the rods than when employed without the hoops.

A comparison of costs between the rich mixture concrete column, carrying light longitudinal reinforcement and a hooped structure of estimated equivalent ultimate strength is interesting. The materials laid down have been assumed to cost as follows:

Cement .... $1.50 per barrel.
(The Canadian barrel weighs 350 lbs. and holds 3.5 cu. ft.)
Aggregate .... $2.00 per cubic yard.
Sand .... $1.00 per cubic yard.
Plain reinforcing .... 3 cts. per lb.
Hooping, fabricated .... 5½ cts. per lb

For a 1 : 1 cement and rock mixture, the cost per cubic yard will be

Cement	$8.10
Rock	1.58
Labor	2.00
Plain steel, ½ per cent	2.03
Total	$13.71

Since the metal is added chiefly as emergency material, it will not be figured in the ultimate strength, which will be taken at 5,000 lbs. per sq. in. A 1 : 2 : 4 concrete (the ultimate strength of which plain may be assumed at 2,000 lbs. per sq. in.) will be rendered equivalent in strength to the 1 : 1 mixture by the use of 3 per cent. of hooping metal.

The cost per cubic yard will then be

Cement	$2.53
Rock	2.00
Sand	.50
Steel hoops	22.28
Labor	2.00
	$29.31

In addition to the greater cost, this column will not possess the stiffness, and probably not the margin of safety, against bending stresses which are found in the cheaper column.

In order to compare the areas of three different types of columns, and their cost per foot of height, it will be assumed that a 10-story building with dead and live floor loads at 200 lbs. per sq. ft. and a roof load of 100 lbs. per sq. ft. is to be constructed. Assume also square floor bays of 15 ft. to a side. It will be seen that the load sustained by a column on the ground floor will be 427,500 lbs. This may be carried,

(*a*) by a structural steel column.
(*b*) by a column of the poorer grade of concrete.
(*c*) by a column of the richer mixture.

A reference to the Carnegie handbook, p. 141, shows that a steel column consisting of two 10-in. channels and two ⅞-in.

plates will be adequate. This column weighs 121 lbs. per running foot. The cost per foot of height will be

Steel at 5 cts. per lb.	$6.05
Fireproofing, 2 ins. thick	.58
	$6.63

A 1:2:4 concrete column with 1 per cent. of longitudinal metal will be figured at 450 lbs. per sq. in. for the concrete and $450 \times 15 = 6{,}750$ lbs. per sq. in. for the steel. The average stress will therefore be $450\ (1 + .14) = 513$ lbs. per sq. in. The gross

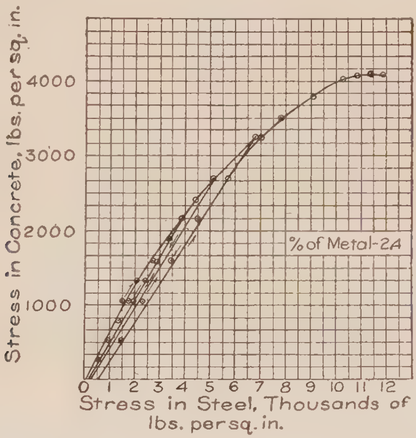

FIG. 8.—TYPICAL BEHAVIOR OF HOOPED CONCRETE COLUMN UNDER HIGH COMPRESSIVE STRESSES.

area required will be $427500 \div 513 = 883$ sq. ins. Hence, a column 29 ins. square will be adequate. Allowing one inch additional for fireproofing we have a column 30 ins. square, the cost of which per foot of height would be

Concrete, including 1 per cent. steel and labor......	$2.55
Forms	.46
	$3.01

The third method employs a 1:1 mixture, the working stress on which will be taken as 1,250 lbs. per sq. in. The area

required will be $427500 \div 1250 = 342$ sq. in. This is the area of a square of 18.5 ins. to the side. Allowing 1½ ins. for fire-proofing, we obtain a column 20 ins. square, the cost of which per foot of height, with ½ per cent. of longitudinal steel would be

Concrete, including ½ per cent. steel and labor......	$1.30
Forms	.32
	$1.62

The areas of the cross-sections in the three cases are—

(*a*) 1.8 sq. ft.
(*b*) 6.3 sq. ft.
(*c*) 2.8 sq. ft.

It is thus seen that the difference between the smallest cross-

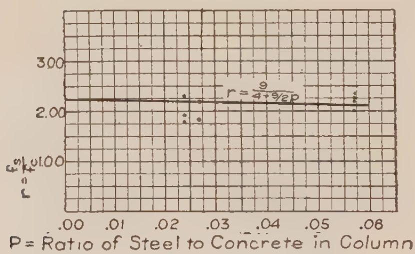

FIG. 10.—CURVE SHOWING THEORETIC EFFECT OF CHANGE IN PERCENTAGE OF METAL ON THE RATIO OF METAL STRESS TO CONCRETE STRESS IN 1 : 1 HOOPED CONCRETE.

section and the largest is 4.5 sq. ft., an item of considerable importance in districts where the rental of floor space is high. On the other hand, the difference in cross-sectional area between the most expensive method of carrying the load, and the cheapest, is 1.0 sq. ft. Having regard then to the fact that the rich mixture column costs only one-fourth as much as the steel structure, there would seem to be a good deal to be said in favor of the stronger mixture.

The writer desires to state that of the experimental work referred to above, part was conducted in the Testing Laboratory of McGill University in Montreal, and part in the Laboratory

of Applied Mechanics in the University of Toronto, the former being done under the general supervision of Professor E. Brown of the Department of Civil Engineering.

Consideration is invited to the following inferences to which an examination of the data at hand seems to lead. Since the experimental evidence supporting these conclusions is, in the opinion of the writer, scarcely extensive enough upon which to base broad generalizations, they are not advanced as being final and conclusive.

1. The rich mixture is more uniform in its elastic properties than the lean mixture and for proportionate stresses, the permanent set is likely to be very much less. The parabolic feature of the stress-strain curve is also less noticeable.

2. The employment of a rich mixture in columns permits of the more economic stressing of the metal longitudinals. It is very probable that a strength equal to that obtained by the use of a 1 : 1 mixture can be secured by the careful grading of the aggregate and the use of less cement.

3. The experiments cited indicate that, for the materials employed, the stress in the metal hoops was approximately twice the axial compressive stress in the concrete core. The metal is, consequently, not economically employed.

4. Theoretically, and experimentally, the variation in the relation of metal stress to axial compressive stress, did not vary greatly with variation in the percentage of metal.

5. A given ultimate strength can be more cheaply secured by a rich mixture lightly reinforced by longitudinals than by the utilization of hooping. The former also secures greater rigidity and safety against bending.

6. For equal safe loads on columns, the lean mixture is probably intermediate in cost between the steel column and the rich mixture lightly reinforced by longitudinals, the latter being the cheapest.

7. The cross-sectional area of the steel column is least for a given loading and the lean mixture greatest. The difference between the cross-sectional areas of a steel, fireproofed column and a rich mixture concrete column is the least of all.

DISCUSSION.

Mr. Brett. MR. ALLEN BRETT.—Referring to the 1 : 1 mixture of trap rock, what kind of trap rock was it, and how finely crushed?

In placing concrete in a job where the columns are figured for a rich mixture, it is absolutely essential for the man running the job to get that 1 : 1 mix down to small sectional columns. Has this method been used in practical work?

Mr. Gillespie. MR. PETER GILLESPIE.—The trap rock ran from 1/8 to 3/4 in. mesh. The crusher dust was screened out, so there was practically no dust present.

I am not aware that practical work has been done, although I know that laboratory tests have been made using that grade of concrete. It is quite possible that the same strength can be secured with less cement. Determinations of voids in the aggregate gave 40 per cent. for an average, showing, I think, that this supposition is justified. This concrete was proportioned, using equal weights of the two materials. To use equal volumes would give substantially the same result.

Mr. Perrot. MR. EMILE G. PERROT.—I would like to ask whether a mixture of 1 of cement and 1 of sand or fine gravel and 2 of trap rock, 1/2 in. and under, would make as strong a mixture as the 1 : 1 referred to.

Mr. Gillespie. MR. GILLESPIE.—I do not think it would. The matrix in your mixture would be so very much inferior that I would expect the strength to be very much less. Still I am inclined to think that possibly instead of a 1 : 1 mixture, a 3/4 : 1 or a 2/3 : 1 would produce a grade of concrete comparable with what I used. This, to some extent, is surmise, as I have no authentic data in mind bearing on the case to which I refer.

Before starting this series of tests, I made a number of compressive tests on two grades of concrete, one with the crusher dust screened out and the other with it left in, the quantity of cement being the same in both cases. I am speaking from recol-

lection, but, I think it is correct when I say that the strength with the fine dust in was 30 per cent. less than it was with the fine dust omitted. Mr. Gillespie

No determination of the quantity of dust was made, except that all under 1/8-in. mesh was screened out. I suppose 15 per cent. would be of that character.

Mr. E. S. Larned.—I think it a fact, within the limits of experiments made that have come to my knowledge, that a mortar approaching 1 : 1 is stronger in tension than neat cement after 28 days or 3 months (the sand being o. k.), and it occurs to me in this connection that with a given amount of properly graded fine material, within the limits of the sand size added to the mixture noted, possibly still greater economy can be secured. It would certainly enable that mixture to considerably bulk the aggregate, and thereby reduce the amount of cement and in consequence the cost. I think it is fair to assume that the compressive strength would be greater. Mr. Larned.

Mr. L. J. Mensch.—I want to ask Mr. Gillespie what was the ultimate strength of the hooped columns. Mr. Mensch.

Mr. Gillespie.—The difficulty encountered in most cases was that the capacity of the testing machine used was only 150,000 lbs. and this was frequently less than the ultimate strength of the columns. In some cases, the columns were retested in a machine of greater capacity. I can tell you from recollection, in the case of one 6 in. column, that the strength was increased 66,000 lbs. beyond what the plain concrete would be expected to sustain. This, in the case cited, was equivalent to increasing the ultimate strength approximately 1,000 lbs. per sq. in. for each per cent. of hooping metal present. In this instance, failure occurred at the middle of the column, through the bursting of three consecutive hoops. Mr. Gillespie.

Mr. Mensch.—In that case I wish to say that Considere quite clearly states that there is no stress in the steel up to the ultimate stress of plain concrete. Now in your case the strength of the plain concrete was 6,900 lbs. per sq. in., hence Considere is perfectly right in that there is no stress, or practically very little stress in the hoops, and that the hoops only become strained after the ultimate stress of plain concrete is reached. Mr. Mensch.

Mr. Gillespie. MR. GILLESPIE.—Would not the gentleman consider that an argument for the rather sparing use of metal in the form of hoops? The metal so placed is not stressed to any considerable extent until conditions approaching the ultimate strength are reached. Metal placed longitudinally, on the other hand, sustains stresses very much greater for the same or equivalent loads. If the former stress be, say 2,000 lbs. per sq. in., while the latter is say 10,000 lbs. per sq. in., it is manifest that in the latter case, the metal is more economically employed. From the evidence, it is undoubtedly true that by the improvement of the mixture, given loads may be more economically carried than by the utilization of considerable quantities of steel either as longitudinals or as hoops. My inferences as given, are not advanced as absolute. To justify the drawing of irrefutable conclusions, a much larger amount of evidence would be required.

Mr. Perrot. MR. PERROT.—I would like to state that the conclusions Mr. Gillespie has drawn regarding the use of rich mixtures for columns and hooping them are correct from a commercial standpoint. In other words, a column, reinforced with additional cement and hoops, is much cheaper than a steel column. I have used such columns in three buildings, and in one building 80 x 100 ft., four stories high, we saved about $1,800 over the cost of steel columns.

Mr. Gillespie has determined the expansion in the hoops as 25 per cent. By pure mathematics I figure the stress in the hoops to be .215 of the vertical load and if we consider the strain to be proportional to the stress we are not far apart. From tests made by the United States Government on full size hooped columns and published in Test of Metals, 1905 and 1906, I have figured Poisson's ratio at 1,000 lbs. per sq. in. on a 1:2 plain mortar column to be .52, which is double what I have assumed, but as the column was without hoops there would be a greater tendency for the concrete to bulge. Where hoops are used, I figured that Poisson's ratio for a 10 in. column 8 ft. long is only .17, with hoops 4 ins. apart, and with hoops 2 ins. apart .217, which is within .002 of what I figured by pure mathematics.

Mr. Gillespie. MR. GILLESPIE.—My determinations of Poisson's ratio gave .25 for an average value. This is larger than is commonly sup-

posed, Professor Talbot, for example, having reported it as .125 or .10. Assuming the correctness of the formula given, and taking Poisson's ratio as .10 and the stiffness ratio as 15, the theoretical ratio between hoop stress and axial compressive stress in concrete will be found as less than two. In other words, the use of a rich, rather than a lean concrete in hooped columns, results in a more economical use of the steel in the hoops. **Mr. Gillespie.**

Mr. Perrot.—The tests I have reference to had no verticals. The government did make a test upon a full size hooped column with the addition of 4 vertical bars, aggregating approximately 1 sq. in., and the column was found to be proportionately stronger. **Mr. Perrot.**

Mr. Arthur N. Talbot.—I have been very much interested in the paper presented. The results add another source of information bearing on the advantage of using rich concrete for column construction. I think that Mr. Howard, of the Watertown Arsenal, perhaps was the first to bring prominently before the public that the rich mixture does give very high strength and that the additional expense of the rich mixture is not large when the amount of strength gained is taken into consideration; and it is easy to cite tests that have been made in various laboratories which come to the same conclusion. **Mr. Talbot.**

So far as the amount of stress in the hooping of columns is concerned, within the ordinary limits of the strength of plain columns, as has been stated here, it has been recognized for some time that the stress in the hooping is very slight. Analytically as well as experimentally it can be shown that this low stress must exist until the hooped column begins to compress much more than it does at any working stress.

So far as the amount of the lateral expansion is concerned, and Poisson's ratio, that will depend very largely upon the mixture used. Possibly the larger value of Poisson's ratio obtained in the experiments cited may be due to the fact that a larger proportion of cement was used than is ordinarily done. But experiments made recently at three different laboratories may be cited, very carefully made experiments, which give a value of the ratio of lateral expansion to longitudinal shortening which range from 1/10 to 1/6 within ordinary working stresses. Of course,

Mr. Talbot. when the ultimate strength of the concrete itself is approached, the value of this ratio runs up very rapidly.

Mr. Mensch. MR. MENSCH.—There is no doubt that a rich mixture of concrete makes the cheapest column. But the difference in cost between a steel column and a column made of a rich mixture is not as great as stated by Mr. Gillespie. Tests made by Mr. F. V. Emperger, of Vienna, show that a stress of at least 300 lbs. can be figured on the fireproofing of a steel column. If the column is banded or if it consists of latticed channels of the Gray type, we can safely allow a stress of 12,000 lbs. on the steel, and at least 300 lbs. on plain concrete. Taking the same plain column Mr. Gillespie shows, I find that the cost of the same right here in Chicago would not be more than $4.00 a lineal foot. So there is not such a great difference between the plain column with longitudinal reinforcement and the steel column. Of course when using a rich mixture of concrete a much cheaper column results; but in a fire a 1:1 mixture is a very dangerous material. Furthermore, such columns cannot be used for the smaller sizes, on account of the monolithic character of the work, and then great stresses are set up in the columns, much greater than generally supposed. I know of quite a number of tests on floors that had to be stopped because the columns and not the girders started to crack.

PROPOSED METHOD FOR THE REINFORCEMENT OF CONCRETE COMPRESSION MEMBERS.

By Robert A. Cummings.*

It is not difficult in these days to understand how the successful use of plain concrete *en masse* has been followed by the development of its structural properties in articulated structures. In the early stages of the industry there was a vague idea that the mere embedment of metal was of advantage. The writer remembers over 30 years ago watching granolithic sidewalks being laid, in which plain square iron rods were embedded below the surface of the sidewalk and near the edges of the block. In reply to his query—Why were the rods embedded? It was said "to be good for the concrete." By a great many practical workers much the same general answer would be given to-day. Indeed, it may be said that the progress in reinforced concrete has been subordinated to the commercial promotion of the metal reinforcement.

Since 1893, when the writer became actively interested in reinforced concrete, the study of its structural properties has engaged his attention. Previous use of concrete en masse having been confined to resisting compressive stresses, it was natural that his efforts should have been directed to increasing the unit value in compression. Little information of a scientific nature was available at that time, but the studies of the practical conditions and theoretical requirements resulted in application for patents for hooped concrete about 10 years ago. This application embodied the individual hoops characteristic of the present methods, and brought to light a number of anticipations applied to concrete blocks, some of them patented in Great Britain 50 years before. Yet, hooped concrete was not applied to columns and struts in the United States prior to the work of the writer.

Since patented protection could not be secured for hooping

* Consulting Engineer, Pittsburgh, Pa.

concrete, attention was directed to improving the details of the steel reinforcement and the methods of holding the same in position. These may be briefly referred to in the proper development. The first requirement was the order of horizontal spacing of the hoops and their complete embedment in the concrete which was a rich mixture having aggregates not exceeding 1 in. in diameter. In order that the concrete might flow between the hoops, minimum spacing was controlled by the size of the aggregate and did not exceed 1½ ins. in any size column. The hoops were held horizontally in position by weaving vertical wires alternately between them. The columns of the Gallego Mills, Richmond, Va., were constructed in this manner during 1903 and have been subjected to a load of a 1,000 lbs. per sq. in. for the past 7 years without the slightest evidence of distress. Later a metallic spacing strip with projecting fingers to mechanically engage each hoop has been employed. At first some difficulty was encountered in securing a satisfactory joint for each hoop. A method of interlocking the ends and later of riveting them was adopted, one end being bent outwardly to contact with the mold and hold the cage-like reinforcement concentrically with the column. Subsequently, an independent device with an outwardly projecting finger clamped to the hoop and a vertical column rod was used to serve the double purpose of holding the hoop concentric with the axis of the column and the vertical rods in their proper position. A rational development of hooped concrete to meet practical and theoretical conditions was thus developed.

But, certain difficulties have been encountered in its application to inclined compression members. For instance, in ribbed concrete arches and diagonal struts the depth of the rib is greater than its width so that circular hooping is not readily adapted. This paper, therefore, will serve to bring up the study of reinforced concrete in compression by referring to a proposed method of reinforcement applicable to compression members built in a horizontal or inclined position.

PROPOSED METHOD.

When a solid is acted upon by a compressive force, there are set up internal stresses tending to disrupt its structure. These

forces may be termed cohesion and friction. Cohesion is the force by which the molecules are held together. Friction is resistence of the molecules to motion. Sand may be considered as a cohesionless body while its resistence to compression is due to friction only. If a tube is filled with sand to a limited height and subjected to pressure, there is a tendency for the tube to bulge outward, which is resisted by the metal shell. When the tube is filled with concrete and subjected to pressure, the resistence is increased by molecular cohesion and less lateral pressure is exerted on the tube. Assuming that the coefficients of friction be the same, the difference between the resistence of the sand and the concrete is the effect due to cohesion.

The stress on hooping varies from a maximum with a cohesionless material to a minimum with neat cement. The value of cohesion for various concretes are yet to be determined.

If a prism of concrete be placed in a compression machine and subjected to a compressive force, it is the universal custom to treat the prism as having failed in direct compression and that its strength is equal to the sectional area divided by the load. This theory has lead up to a general misinterpretation of internal stresses in compression tests. The characteristic pyramidal shaped failures of cubes in compression are due to the friction between the plates of the testing machine and the specimen, preventing lateral misplacement of the molecules. The introduction of a greased surface has reduced the friction sufficiently to show that failure takes place along lines parallel to the direction of the pressure after the elastic limit of the material has been exceeded. In consideration of this fact, experimental studies have been made by placing reinforcement at right angles to the direction of pressure and at variable distances apart. The result of the experiments on metal sheets has conclusively shown that the strength of concrete can be greatly increased. It has also shown that the results are due to the close spacing of the layers of reinforcement and further verifies the well known increased compressive resistance of mortar in the joints of masonry.

The tests referred to also indicate that the best percentage of reinforcement is capable of being determined within reasonable limits or that which produces the greatest result with the least

amount of metal. In almost all construction in reinforced concrete practical methods largely govern the distribution of metal. This is particularly true in column work where the concrete is placed vertically so that the use of wire netting or sheet metal in horizontal layers is out of the question. Hooping remains the only practical method of safely increasing the unit compressive strength of concrete for such work.

In inclined compression members, however, where the con-

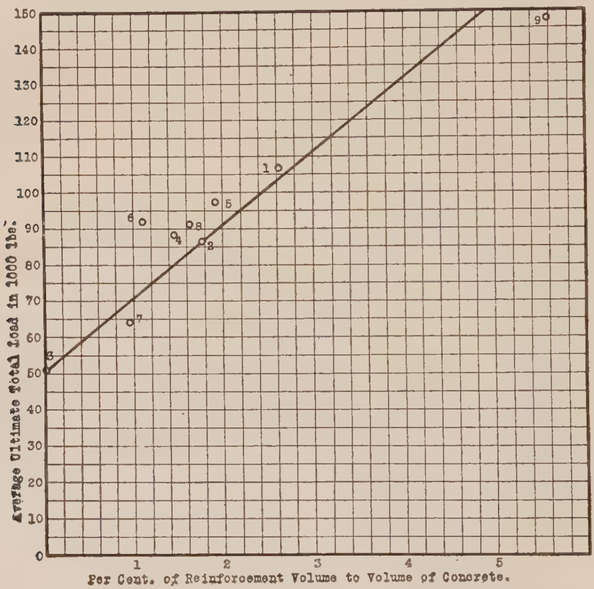

FIG. I.—DIAGRAM SHOWING RELATION OF ULTIMATE LOAD TO REINFORCEMENT.

crete is deposited from one side of the member, the difficulty of using lateral reinforcement is reduced, and some time ago the writer suggested the use of concentric and interlocking hoops combined with longitudinal reinforcement for resisting shear in arch ribs. This has been followed by some of his experiments on the effect of lateral reinforcement using different weights and disposition of the metal. These tests were not carried out with the degree of refinement and accuracy desired, hence simply indicate what one might look for in further studies. See Table I.

TABLE I.—TESTS ON CONCRETE COLUMNS WITH VARIOUS TYPES OF LATERAL REINFORCEMENT.

No.		1	2	3	4	5	6	7	8	9
REINFORCEMENT.										
Kind		Welded Hoops.	Welded Hoops.	Plain Concrete.	Concentric Circles.	Wire Mesh.	Metal Lath.	Looped Wire.	Wire Spiral.	Plain Circular Hoop.
Dimensions		5/8" x No. 8 (B & S) 7" d.	1" x No. 16 (B & S) 7" d.	....	3", 5" & 7" d. No. 7 (B & S)	1 7/16 □ No. 6 (full)	1 3/8 x 3" No. 9	4" x 9" No. 7 (B & S)	6¾" d. No. 7 3½ turns	6.3" d. 3/8"
Spacing of planes	ins.	2	2	....	1¼	1¼	1¼	1¼	1¼	1¼
Weight	lbs. oz.	6—14½	4—10½	....	3—13½	6 9	3 13½	3 3	3—15	11—13
Volume	cu. ins.	24.38	16.34	....	13.58	23.19	13.58	11.26	13.91	41.74
TEST PIECE										
Diameter	ins.	8	8	8	8	8	8	5 x 10 sq.	8	8
Length	ins.	24	24	24	24	24	24	24	24	24
Volume	cu. ins.	923.64	923.64	1296.38	923.64	1206.38	1206.38	1200.	885.89	748.15
Cross-sectional area	sq. ins.	*38.485	*38.485	50.266	*38.485	50.266	50.266	50.0	*35.787	*31.173
Per cent. of reinforcement volume to concrete volume		2.64	1.77	....	1.47	1.92	1.12	.94	1.62	5.58
STRENGTH. (Average of 3 tests.)										
Total ultimate load	lbs.	106,845.	87,155.	51,125.	87,825.	97,030.	91,547.	63,908.	91,247.	147,923.
Shortening	per ct.	....	....	....	1.91	1.47	1.53	1.38	1.67	3.8
Unit ultimate load	lbs. per sq. in.	2766	2265	1017	2281	1930	1821	1278	2550	4745
Per per cent. of reinforcement	lbs. per sq. in.	1048	1280	....	1552	1005	1626	1360	1574	850
Per lb. of reinforcement	lbs. per sq. in.	401	486	....	593	294	474	401	648	401

*Cross section of core only.

NOTE: In all specimens except 1 and 2 reinforcing planes were found out of position, some being as much as 2½ ins. apart on one side. Hence these tests are not satisfactory, and cannot be accepted as conclusive.

An examination of the curve plotted from the ultimate load and percentage of reinforcement indicates strength value directly proportional to the amount of reinforcement. Also that the best disposition of the metal is that which intersects the resultant of the meridianal forces and the lateral deformations. See Fig. 1.

It has not been thought advisable to discuss the relative merits of added cement to the concrete instead of reinforcement as it is complicated by the excessive internal stresses due to the shrinkage of rich mixtures which tend to result in cracks, besides the question is largely a simple arithmetical problem.

The writer has applied the proposed method of lateral reinforcement in his practice with very encouraging results, particularly in concrete piles cast horizontally on the ground. The extraordinary severe treatment to the head when the hammer strikes a concrete pile directly, is not duplicated in any other class of work. In a case where the reinforcement was distributed in horizontal wire spiral planes spaced 2 ins. apart in the head of the pile, a test was made on a pile about 30 days old. A hammer weighing 6,500 lbs. was used, falling from 4 to 7 ft. This pile was driven through very sandy gravel into a bed of fine sand during a period of 3½ hours. About 900 blows were struck on the head of the pile with no deterioration to the concrete. This work opens up a broad field of usefulness for the proposed method of reinforcement.

DISCUSSION.

Mr. Talbot.

Mr. Arthur N. Talbot.—The method of construction given by Mr. Cummings may prove applicable in cases other than ordinary building construction, where, for example, the section of the compression piece is irregular or is changing in size, as it might be in the case of the rib of an arch. Here is a chance to put in a lateral reinforcement, if we may call it such, having a rectangular section, or irregular section, or a changing section. There is a possibility in that direction.

Now, in the specimens tested, as I understand it, the distance apart of this reinforcement was 1¼ ins. I would like to ask the greatest distance it would be practicable to use in such a case in order to get the same strength; supposing the amount of reinforcement double in weight in any single plane, would it be possible to put it twice as far apart? Taking a section 4 ft. across, how far apart would it be possible to put the reinforcement and yet get the strength shown by these tests?

Mr. Cummings.

Mr. Robert A. Cummings.—The tests that have been made by others, particularly some French and German tests, show that if the layers are placed too far apart a very much less ultimate strength results. There is, therefore, a limit to which you can place the layers. My work in concrete piles is a very good example of the practical experience in reinforcement applied in layers. The reinforcement is placed 2 ins. on centers and no difficulty has been experienced in placing the concrete in a case of that kind.

However, in the case of an irregularly shaped member, for instance an arched rib 2 ft. wide and 6 ft. deep, I should be disposed to use a system of interlocking hoops. I know of tests in which a very rich mixture was used and in which the ultimate loads ran up to very nearly 11,000 lbs. per sq. in. on such a disposition of the reinforcement. I think the test piece was about 8 by 18 ins. in cross section.

Mr. Perrot.

MR. EMILE G. PERROT.—As a matter of interest, I might state that Mr. Cummings' system of reinforcing concrete I believe has been a subject of investigation some years ago. I believe Prof. Norton made some tests on small cubes about 4 x 4 ins. which were reinforced horizontally with wires forming a mesh, placed at regular intervals in the height, and the reinforcement increased the strength of the cubes considerably.

LONGITUDINAL REINFORCEMENT IN CONCRETE COLUMNS.

By Sanford E. Thompson.*

Of the three common methods of strengthening concrete columns so as to reduce the size below that which would be required by an ordinary mixture of plain concrete—namely a rich mixture, longitudinal reinforcement, and hooping—each has its advantages and limitations.

By increasing the percentage of cement there is an increase in the strength of the concrete per square inch of section. By inserting vertical reinforcement, this receives a share of the compression and thus permits heavier loading. By hooping or banding, the ultimate strength is increased and the column is rendered more ductile.

The writer has presented on previous occasions† the limitations of hooping, which although very effective in increasing the ultimate strength of the column, does not greatly advance the point of the first beginning of the failure, because the hoops do not get into action until the concrete begins to crush and expand laterally so as to put tension on the hoops. Columns with longitudinal reinforcement imbedded in them to reduce their size are apt to be more expensive than plain concrete columns of equal strength, but the occasional criticisms that vertical bars do not add to the strength of the column are absolutely unfounded by either theory or test. On the contrary, as indicated by proofs given below, both theory and experiments show that the longitudinal reinforcement, properly placed, does actually increase the strength of the column.

The principle is very simple. When a load is placed on a column of any material whatever, it is shortened by a small amount, but this shortening within working limits is substantially

*Consulting Engineer, Newton Highlands, Mass.

†*Transactions Am. Soc. of C. E.*, Vol. LXI, p. 46; *Journal Assn. of Eng. Socs.*, June, 1907, p. 316.

in proportion to the load placed upon it; that is, with a column of any homogeneous material if the working load is doubled, the amount of shortening is also doubled. Now, if the vertical steel bars are imbedded in concrete, they also must shorten with the concrete when the load is applied, and therefore they relieve the concrete of a portion of its load. It is physically impossible to prevent such vertical steel taking a part of the load unless the steel slips or buckles, and since the power of resistance of the steel bars to shortening is greater than that of the concrete, the load necessary to shorten them is proportionally greater than would be required for concrete of the same area. The action of structural steel reinforcement is similar, provided the bond between the steel and the concrete is perfect. This bond is more difficult to obtain with vertical structural steel than with vertical bars, and tests with latticed angle bar reinforcement* have indicated a less effective increase of strength with this structural steel than with vertical bars.

Considering then only columns with bar reinforcement, the question is whether these vertical steel bars do slip or buckle. Evidently they cannot slip if the ends are securely held by the concrete, and this is always the case if they are properly butted or lapped for a sufficient length. As to buckling, tests have proven conclusively that vertical bars, such as are used in columns, when imbedded in concrete, will not buckle until the elastic limit of the steel is reached, and beyond this point of course no steel or other material is expected to do any service. Many of the tests at the Watertown Arsenal, for example, were made with vertical bars imbedded in columns 12 ins. square and 8 ft. long, with absolutely no loops or horizontal steel of any kind placed around these vertical bars to hold them in place, that is, the bars 8 ft. in length were placed in the four corners of the column—in some tests only 2 ins. from the surface—and simply held in place by the 2 ins. of concrete itself.† There was no sign whatever of buckling until the compression was so great that the elastic limit of the steel was passed, when of course nothing further could be expected of it.

*M. O. Withey, *Proc. Am. Soc. for Test. Mats.*, Vol. IX, p. 469.
†*Tests of Metals, U. S. A.*, 1905, p. 344.

These tests at the Watertown Arsenal and, so far as the writer has been able to discover by examining all the experiments on record, all other tests of full size columns made in this country further bear out the fact that vertical steel bars imbedded in concrete increase the strength of the column, and it can be further shown that these tests bear out the theory by which the strength

TABLE I.*—STRENGTH OF PLAIN VS. VERTICALLY REINFORCED CONCRETE AND MORTAR COLUMNS. COLUMNS 12×12 INS. HEIGHT 8 FT. AGE OF MORTAR AND CONCRETE 6 MONTHS. WATERTOWN ARSENAL.

Proportions.			Plain Concrete or Mortar Columns Actual Strength lbs. per sq. in.	Reinforced Columns.				Reference to "Tests of Metals" U.S.A.
				Reinforcement.				
Cement.	Sand.	Stone.		Description.	Ratio Area Metal to Area Col.	Actual Strength lbs. per sq. in.	Computed Strength based on col. (4) and a ratio of $n=15$ lb. p. sq. in.	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	2	0	3070	8-$\frac{3}{4}''$ round bars	0.029	4200	4290	1905 p. 377
1	3	0	2380	8-$\frac{3}{4}''$ round bars	0.029	3840	3320	1905 p. 377
1	4	0	1520	8-$\frac{3}{4}''$ round bars	0.029	3380	2120	1905 p. 377
1	5	0	1080	8-$\frac{3}{4}''$ round bars	0.029	2810	1510	1905 p. 377
1	6	0	1080	13-$\frac{3}{4}''$ round bars	0.046	3900	1780	1905 p. 377
1	1	2†	1720	4-$\frac{3}{4}''$ twisted bars	0.014	2890	2060	1904 p. 386
1	2	3†	1769	4-$\frac{3}{4}''$ twisted bars	0.014	2010	2100	1904 p. 386
1	2	4	1413	4-0″ 0.74×0.74″ trussed bars	0.014	1900	1689	1906 p. 538
1	2	4†	1710	4-$\frac{3}{4}''$ twisted bars	0.014	1990	2050	1904 p. 386
1	2	4‡	2400	8-$\frac{3}{4}''$ twisted bars	0.029	3700	3360	1907 p. 242
1	3	6	1450	8-$\frac{5}{8}''$ corr. bars	0.019	2290	1840	1904 p. 379 1906 p. 535

† $\frac{1}{2}$ to $1\frac{1}{2}$ in. pebbles.
‡ Age 17 months 22 days.

of the combination of steel and concrete may be computed and is computed in practice.

To present evidence of this statement, I submit below some of the average results obtained from the various tests. The results are given in round numbers simply to show that the steel does increase the strength of the column. The values of the tests at the Watertown Arsenal also show how closely the increase in strength corresponds to that which would be figured by the ordinary formula, and especially how far the computed values are on

*Quoted by permission from Taylor and Thompson's "*Concrete, Plain and Reinforced*," Second Edition, 1909, p. 493.

the safe side. Similar computations might be made from the other series, but for the purposes of this paper they are unnecessary.

Tests at Watertown Arsenal. Table I gives results of representative column tests, made by Mr. J. E. Howard at the Watertown Arsenal, selected from Tests of Metals, 1904, 1905, 1906, and 1907. The results of the computed strengths as well as the actual tests are given. It is noticeable that the actual strength is almost always more than the theoretical, and this is especially the case with the leaner mixtures because the modulus of elasticity of the leaner concrete is lower, and therefore the ratio of 15 is very conservative.

Tests at Massachusetts Institute of Technology. One of the first series of tests on reinforced concrete columns was made at the Massachusetts Institute of Technology,* and from the figures below it will be seen that the average actual breaking load is much greater than the computed breaking strength:

Average breaking strength, Plain columns ....1.750 lbs. per sq. in.
Vertically reinforced columns, 2,370 lbs. per sq. in.

The strength of the reinforced columns is considerably greater than the computed values of the experimenters.

Tests at University of Illinois. Although individual tests made at the University of Illinois may be cited where the strength of a plain column is greater than the strength of a similar vertically reinforced column, an average of the tests taken from page 14 of Bulletin No. 10, as given by Prof. Talbot, shows:

Plain columns .... 1,550 lbs. per sq. in.
Vertically reinforced columns .... 1,750 lbs. per sq. in.

Tests at Minneapolis. The tests at Minneapolis† were made on small sized columns, and the results therefore are not of so great value as some of the other tests. However, comparison of

* Discussion by Prof. Lanza, *Transactions Am. Soc. C. E.*, Vol. L, p. 487.

† *Engineering News*, Dec. 3, 1908, p. 608; also discussion *Engineering News*, Jan. 7, 1909, p. 20.

plain columns with those vertically reinforced which are not cut up by horizontal reinforcement is very marked, the average being:

Plain columns	2,020 lbs. per sq. in,
Vertically reinforced columns	2,300 lbs. per sq. in.

*Tests at University of Wisconsin.** Averaging the results of tests of columns with no reinforcement and those of the same kind of concrete reinforced with vertical bars and no spiral reinforcement gives:

Plain columns	2,033 lbs. per sq. in.
Vertically reinforced columns	2,438 lbs. per sq. in.

CONCLUSION.

The references given cover all the important series of column tests made in the United States to date, and not a single average of similar specimens but shows a decisive increase in strength of columns reinforced with vertical steel bars over those unreinforced. Furthermore, although this is not taken up in the above discussion, it may be shown that tests bear out conclusively the conservatism of computing the value of the vertical steel bars by the ordinary formulas based on the ratios of the moduli of elasticity of steel and concrete.

* M. O. Withey, *Proc. Am. Soc. for Test. Mats.*, Vol. IX, 1909, p. 477.

CONCRETE FOR MARITIME STRUCTURES.

By Chandler Davis.*

Intercourse between countries by water was developed almost as quickly as the travel by land, and as the size of ships increased the primitive method of beaching the vessel at high tide or hauling the ship out on the beach had to be abandoned and artificial landing places built. The first harbors were the naturally protected points, land locked with tongues of land fending off the waves and forming basins offering shelter from the winds. Later, as commerce increased, it was found necessary to build seaports at points offering no protection from storms, in open roadsteads, as are found along the coasts of Italy, and harbors were projected at points which had no natural protection from the weather and waves, and breakwaters were designed and built. The Romans built a large number of such harbors along the shores of the Mediterranean some of these are still in use, others in ruin, or, like the old harbor of Rome, Ostia, no longer a seaport but now lying about two miles inland.

Various materials have been used in their construction, stone and wood being those usually employed, in latter days, however, concrete has superseded the general use of such materials, especially in foreign countries and it is proposed to give a short description of some maritime structures built of concrete.

Concrete has been used in subaqueous foundation work in many ways. The most natural and simplest method was to take advantage of the hydraulic properties of the cement and deposit it under water and let it harden. The concrete so deposited did not always properly set and very unsatisfactory results were frequently obtained. In the early days the cement was not of uniform quality and could not be depended upon. This lack of uniformity caused the outer faces of the concrete to crumble away on the removal of the molds, and holes several inches deep

* Consulting Engineer, 11 Broadway, New York.

appeared in the face of the mass and the entire block did not seem to be of good sound concrete.

An examination of a quay wall constructed of concrete placed *en masse in situ* along the North River in the harbor of New York (Fig. 1), resulted in the abandoning of this plan of construction, and the use of base blocks manufactured on land and set on the foundation by means of a derrick was again reverted to. The employment of concrete laid *en masse* however, has been successfully used in places where the conditions

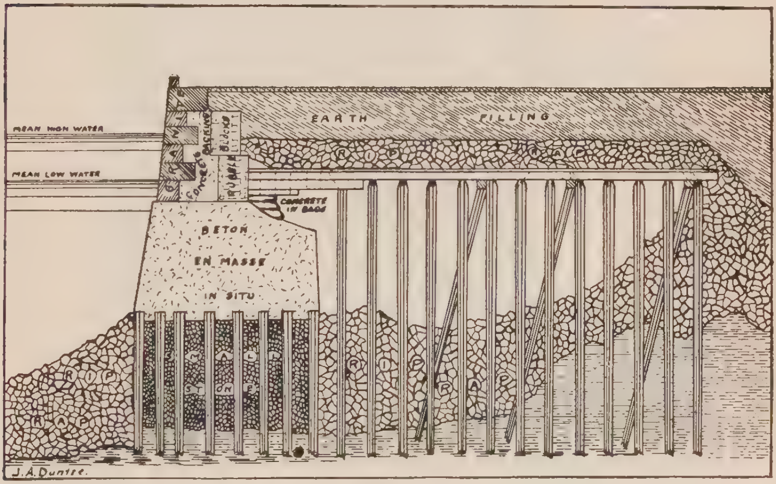

FIG. 1.—BULKHEAD WALL BUILT BEFORE 1876 AT CANAL STREET, NEW YORK, N. Y.

were most favorable and the water was clean and the concrete subjected to little or no current and only a small wave action; but unless such is the case, good results cannot be expected. The water must be practically quiet inside the cofferdam so as not to disturb the freshly laid cement, thus washing it out of the mixture and preventing hardening. Even then it is almost impossible to avoid laitance. Very good results have been obtained by the Department of Docks of the City of New York, but this method of depositing concrete is used only when success is assured.

A radical change was introduced into the Department of Docks when Mr. G. S. Greene became its Engineer-in-Chief in 1876 and he developed the wall shown on Fig. 2. This wall,

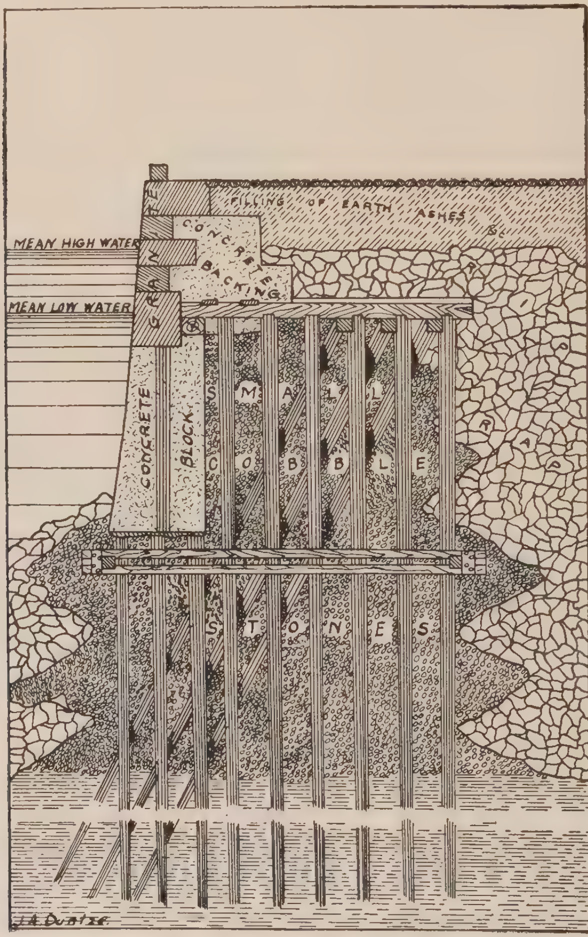

FIG. 2.—SECTION OF BULKHEAD WALL IN USE ON NORTH RIVER, NEW YORK, N. Y.

designed as a quay or river front wall on the North River was founded on a layer of slit so thick that hard bottom could not be reached by the longest piles obtainable, is a floating wall but

still has filled all the necessary requirements. In order, however, to make this structure stable and prevent movement, it was found necessary to dredge the river bottom to a depth of about thirty feet below mean low water, and make a new and more compact

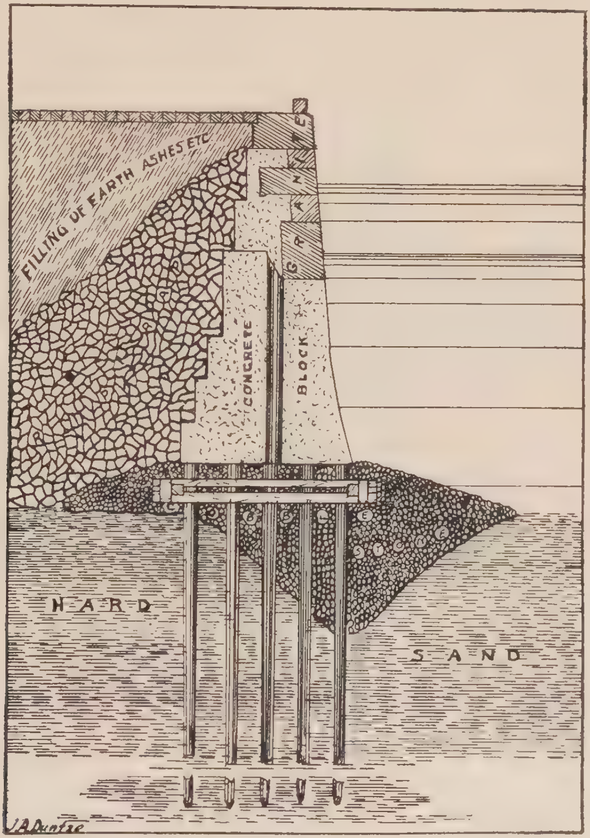

FIG. 3.—SECTION OF BULKHEAD WALL FOR HARD SAND FOUNDATION, NEW YORK, N. Y.

foundation by depositing a rip-rap bank with a cobble core before the driving commenced and driving the piles through this fill. On these piles were placed large concrete base blocks weighing about seventy tons. As it is impossible to cut off piles at a uniform grade under water, the foundation of the block was

made level by means of a mattress placed on top of the piles, this was filled with mortar mixed 2½ parts Portland cement to three parts sand screened to ¼ inch, and in this manner a perfectly smooth and level bed was obtained for the base blocks.

Figs. 3, 4, 5 and 6 show various modifications of this wall

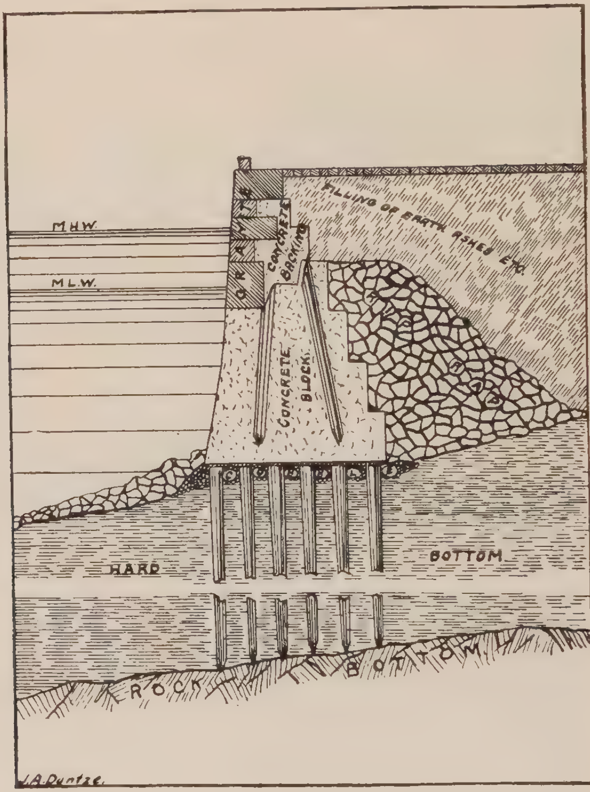

FIG. 4.—BULKHEAD WALL ON PILES DRIVEN THROUGH HARD BOTTOM TO ROCK BOTTOM, NEW YORK, N. Y.

adapted to the local conditions. In hard bottom (Figs. 3 and 4) the relieving platform is omitted. If the rock is sufficiently near the surface to obviate the necessity of using piles, the bottom in such a case, after being cleaned off, it leveled up with concrete in bags and floated off with a rich mixture of gravel and

concrete to make a smooth bed for the base blocks (Figs. 5 and 6).

There is no reason why the quay wall just described should not survive centuries. It was constructed entirely without metal, wooden treenails being used to fasten the timbers together, the

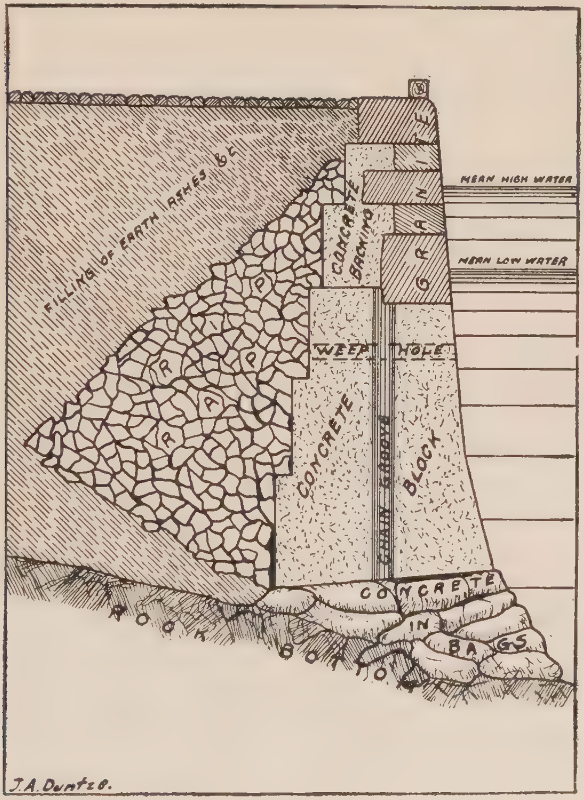

FIG. 5.—BULKHEAD WALL ON ROCK FOUNDATION, NEW YORK, N. Y.

lumber and piles are entirely covered and thoroughly protected from the air and the entire structure should therefore last forever. Frequent examinations have failed to reveal any damage to the cement by action of salt water; it must be noted here, however, that everything connected with this work was carried on with the utmost care, under constant supervision and the

materials used were the best of their kind to be obtained in the market and they were thoroughly inspected and tested; concrete manufactured in this manner should withstand the action of salt water and experience has shown that it does. This type of wall was first constructed in 1876, and certain sections have been

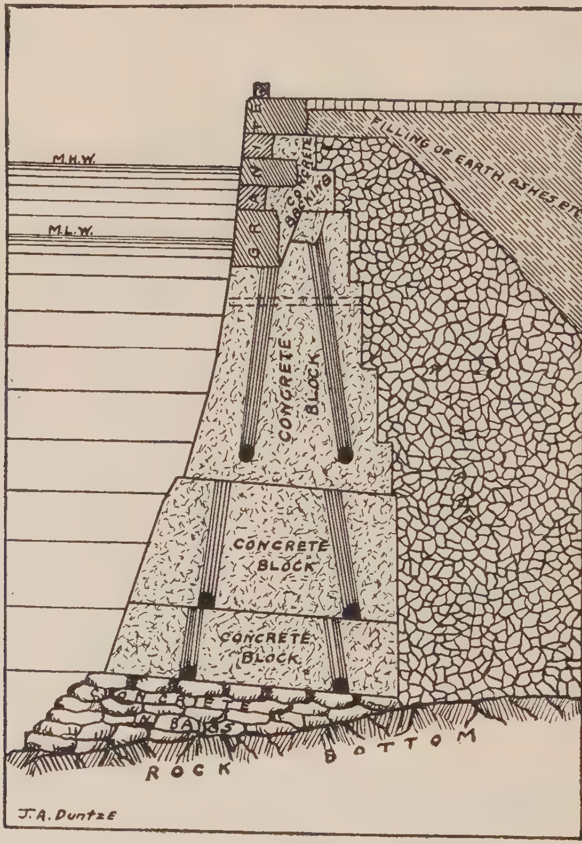

FIG. 6.—BULKHEAD WALL ON ROCK FOUNDATION, NEW YORK, N. Y.

completed and tested for a period over thirty years, and are to-day apparently as sound as when first completed.

In Southampton, England, the chief deterioration of the ferro-concrete structures, built by the London and Southwestern Railway, took place well above the tide, where the concrete piles

and superstructures were subjected to the action of the air and rain only. This was also noted by the Italian engineers on their breakwaters; there the concrete blocks above water, which were alternately wet and dry, showed signs of crumbling on their faces and had to be repaired from time to time. At Southampton, however, the trouble was probably due to the fact that the structures, which showed signs of deterioration were overloaded and were subjected to the moving loads of heavy freight trains and the vibrations of heavy coal hoists, as the other wharves at that place constructed at the same time, with identically the same care and the same materials, but not subjected to the heavy overloads, show no signs of deterioration and are standing the wear and tear of time well. The best English Portland cement was used in this work, and none was allowed in the structure unless it had been thoroughly tested.

The coal barge jetty at Southampton built by the railway (Figs. 7 and 8), is founded on piles made of one part Portland cement and three parts sand and gravel mixed, this sand and gravel mixture was dredged directly from the Solent and is practically a uniform mixture of one part sand and two parts gravel. The piles are reinforced and were driven with a steam hammer through a chalk fill into a hard bottom of well packed sand and gravel. The entire structure is of reinforced concrete. The maximum weight possible to place on any one pile is seventeen tons. The structure has been in use over eight years and already shows signs of deterioration. This is probably due to the excessive vibration caused by the coal hoisting machinery and the moving of this immense crane along the dock. This wharf was the pioneer dock built by this road, and is probably too light. All the other docks which are not subjected to similar vibrations as the coal dock, do not show any signs of wear and in fact have cost practically nothing for maintenance; they were designed for the same heavy deck loads.

The Southwestern Railway has adopted the Hennebique system in their work and have had great success with their docks. Figs. 9, 10 and 11 show a few of the larger undertakings at their Southwestern Railroad Terminal, and Fig. 12 shows the Woolston Jetty on the Itchen opposite to the railroad docks.

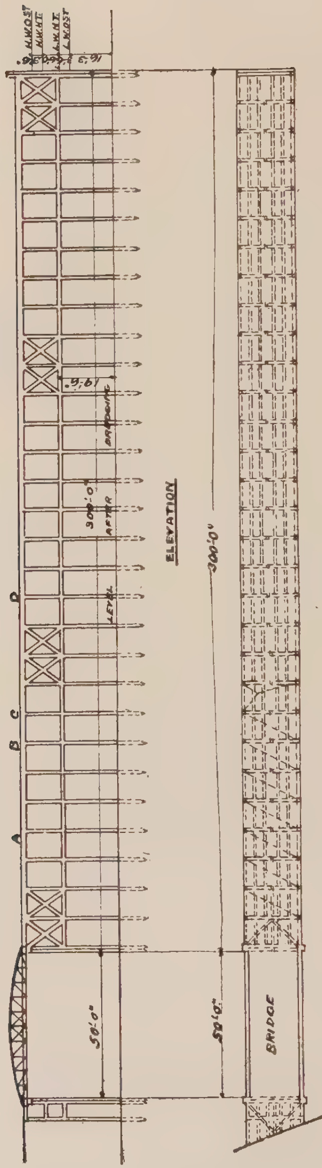

FIG. 7.—DETAILS OF COAL BARGE QUAY OF LONDON AND SOUTHWESTERN RAILWAY AT SOUTHAMPTON.

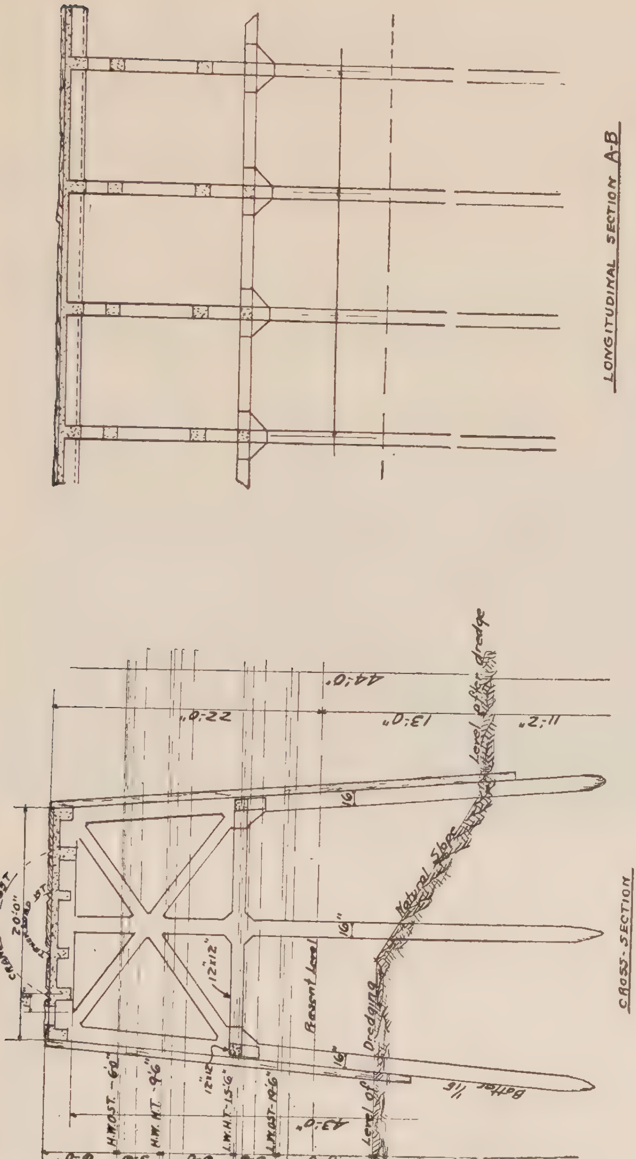

FIG. 8.—CROSS-SECTIONS OF COAL BARGE QUAY SHOWN IN FIG. 7.

This landing was built in the year 1899 and to date has cost nothing for repairs except for the damage done by a large steamer having been in collision with it, and these repairs, however, were very slight.

In the case of the Southampton structures deterioration due to the action of salt water has not been noticed to have taken place, and Mr. F. E. Wentworth-Shields, Dock Engineer of the London and Southwestern Railway, is of the opinion that if great

FIG. 9.—COAL BARGE QUAY, SHOWING FORMS READY FOR CONCRETE.

care is exercised in making and placing concrete an impermeable material will be obtained which can withstand the action of salt water.

The large Eastham locks built by them at the entrance of the Manchester ship canal were begun in 1887 and have been in constant use since 1892, and although the tidal range amounts to 32 feet at spring tides the concrete to-day is even better than the day it was deposited. Mr. W. Henry Hunter, Chief Engineer of this Company, states "My experience in the use of Portland cement in salt water has now extended over thirty years and

I have not known of any failure of such work when the concrete has been properly mixed and deposited," thus corroborating Mr. Wentworth-Shields' opinion.

The development of Manchester was done at the expense of Liverpool, which is one of the largest and most important seaports of England and to-day is one of the principal harbors of the world. The gradual increase in the size of ships obliged more

FIG. 10.—COAL BARGE QUAY, SHOWING FORMS REMOVED.

progressive harbors, if they wished to retain their importance as commercial cities, to increase their landing facilities and enlarge their docks. The Liverpudlians have taken advantage of all modern improvements and they have erected a great many ferro concrete structures. The oldest, built in 1899-1901, the Cattle Wharf, Prince's Stage, is shown in Fig. 13. This structure consists of a deck of reinforced concrete, resting upon green heart piles. The superstructure upon which coastwise cattle are received and sorted, consists of the usual Hennebique beam and floor design. Mr. Miles Kirk Burton, General Manager and Secretary of the Mersey Harbor Board, states that the underside

of the deck and beams have received considerable repairs. This portion of the structure although never actually under water is subjected continuously to the influence of moist air. Rust marks, owing to the corrosion of the metal reinforcement, have appeared, pieces of concrete have broken away from the underside, while the upper side of the deck although frequently washed down is

FIG. 11.—COAL BARGE JETTY AT SOUTHAMPTON, LONDON AND SOUTHWESTERN RAILWAY.

in perfect condition. All defects have been carefully repaired with Portland cement mortar. The reinforcement may have been located too near the surface of the beams or slabs, the quality of the concrete, however, was the fundamental cause of the defects noticed in this structure and in the others erected at Liverpool, as it was the permeability of the concrete which allowed the moisture to act on the metal armature. Continuous exposure to

dampness combined with a porous concrete will soon develop the weak points in any concrete structure, and too great a stress cannot be laid on the necessity of rigidly inspecting such work during its erection, and even then in spite of such care defects will develop as was the case at Liverpool.

Prince's Dock Wharf (Fig. 14) is built throughout of ferro concrete and was completed in 1905. The reinforced concrete piles, resting on the sandstone bottom of the dock, are thoroughly

FIG. 12.—WOOLSTON JETTY, WOOLSTON ON THE ITCHEN, SOUTHAMPTON.

braced with horizontal and diagonal braces. The superstructure consists of caps, rangers and flooring, all of reinforced concrete, designed in accordance with the Hennebique system. Besides the defects mentioned above for the cattle wharf, some trouble has been experienced in obtaining a good connection between the piles and diagonals. A number of joints were found defective, these were cut out and filled with a rich Portland cement mortar and to-day, after five years' use, the structure is in a very satisfactory condition. This wharf is designed to carry safely a live load of 667 lbs. per sq. ft.

Fig. 15 shows Dock No. 7 of the Manchester Ship Canal.

The Engineers of the Liverpool docks have used Portland cement in salt water in large quantities since 1872 and so far no failures due to deterioration have been reported. All of the cement used, however, after being carefully inspected and tested, is stored in a perfectly dry place until required and all work is carried on in a thorough and workmanlike manner.

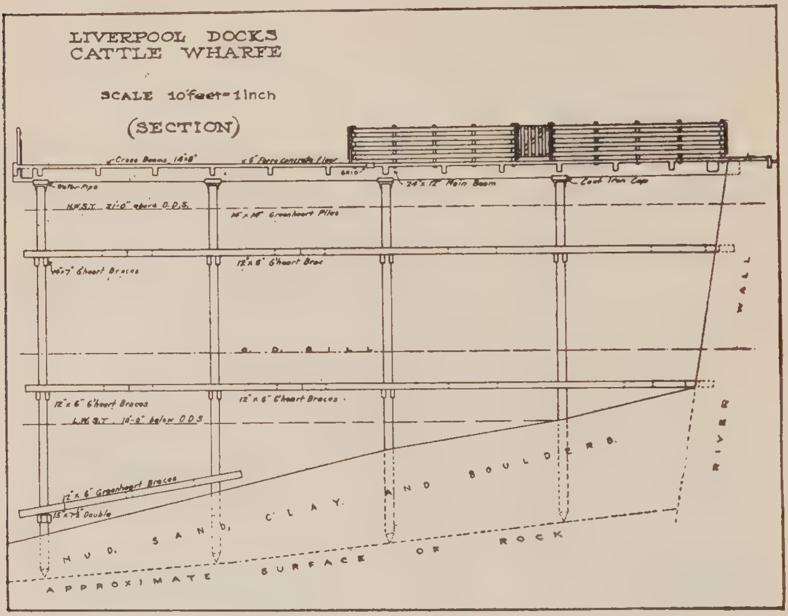

FIG. 13.—DETAILS OF CATTLE WHARF, LIVERPOOL DOCKS.

Two other dock quays consisting of concrete superstructures, resting on green heart piles have developed the same defects as the Cattle Wharf and Prince's Dock Wharf, proving the necessity of obtaining an impermeable concrete. Properly mixed concrete when entirely submerged will last longer than when alternately wet and dry or continuously exposed to moist air, is a phenomenon which has also been noted by the Italian engineers in their study of concrete in their own and other countries.

Commander Luigi Luiggi, Ispettore Superiore del Genio

Civile, Italy, has had considerable experience in the construction of concrete maritime works both in Italy and in the Argentine Republic. He always employed a rich impermeable mortar, well mixed, when the concrete was exposed to the action of the sea water. The concrete directly subjected to the wave action is protected with granite or faced with a mixture of mortar about two inches thick and made of one part of cement and one part of sand. This mortar was thoroughly mixed and well worked

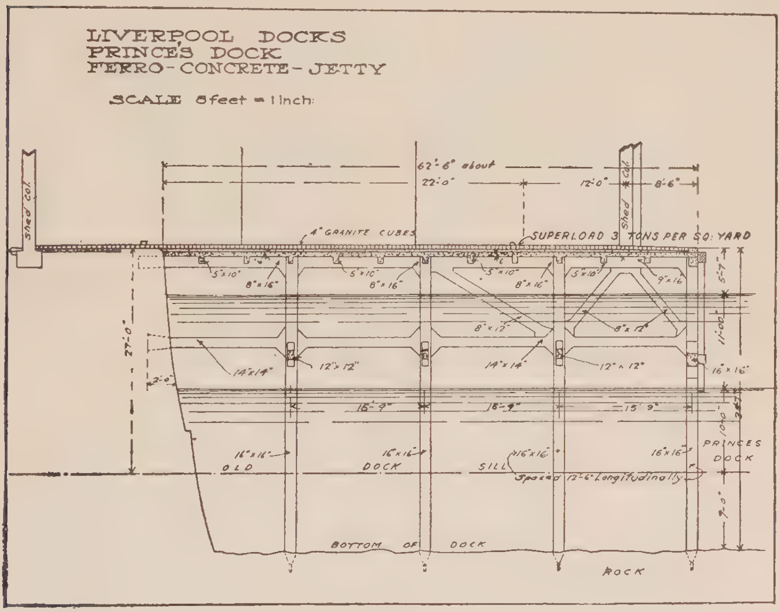

FIG. 14.—DETAILS OF PRINCE'S DOCK, LIVERPOOL.

against the molds and backed with a twenty-inch layer of concrete mixed 1 : 2 : 3 while the remainder of the wall is composed of 1 : 2 : 5 concrete, mixed medium wet, so that when it is well rammed, the water will show on the surface, and the resulting structure is absolutely waterproof. The concrete, however, must be absolutely impermeable or the life of the building will be limited as the salt water percolating through the concrete will soon cause it to deteriorate and the mass will eventually crumble away.

Fig. 16 (Plate I) shows the dry dock built by Commissioner Luigi Luiggi at the Argentine Naval Station at Bahia Blanca. The rich concrete backing is shown cross hatched. This dock was put into commission in 1902 and is absolutely tight, not showing any signs of leaks. Great care was taken, however, in the placing of the concrete to see that everything connected with the work was done in the best manner and that the various layers of

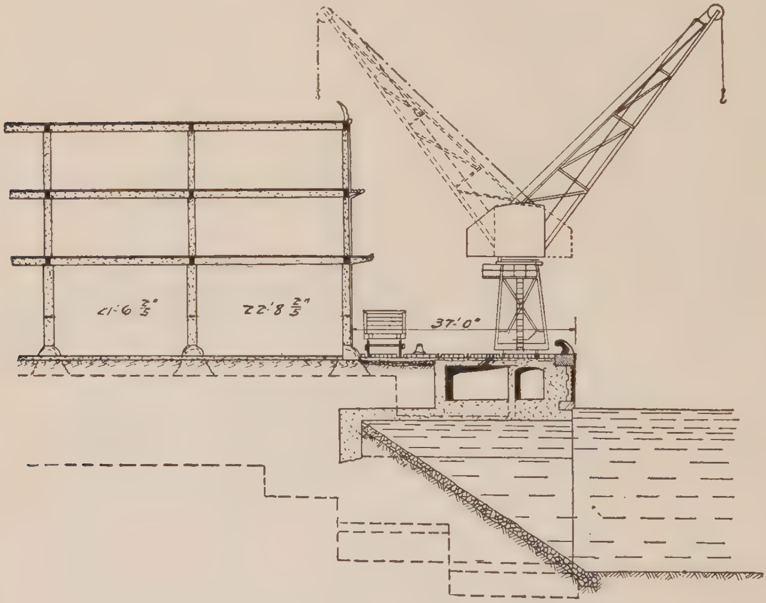

FIG. 15.—DETAILS OF DOCK NO. 7, MANCHESTER SHIP CANAL.

concrete were laid so as to avoid all chances of leaks occurring at the horizontal joints between the old and new concrete.

In the construction of the Italian Breakwaters several plans were developed and finally they were built with concrete face blocks laid in courses, as experience showed that a wall constructed in this manner and in accordance with Figs. 17, 18 and 19, withstood the action of the salt water of the Mediterranean and the heavy blows of the high waves better than if the blocks had simply been deposited without care or order. Figs. 20 and 21 show additional types of breakwaters used by the Italians.

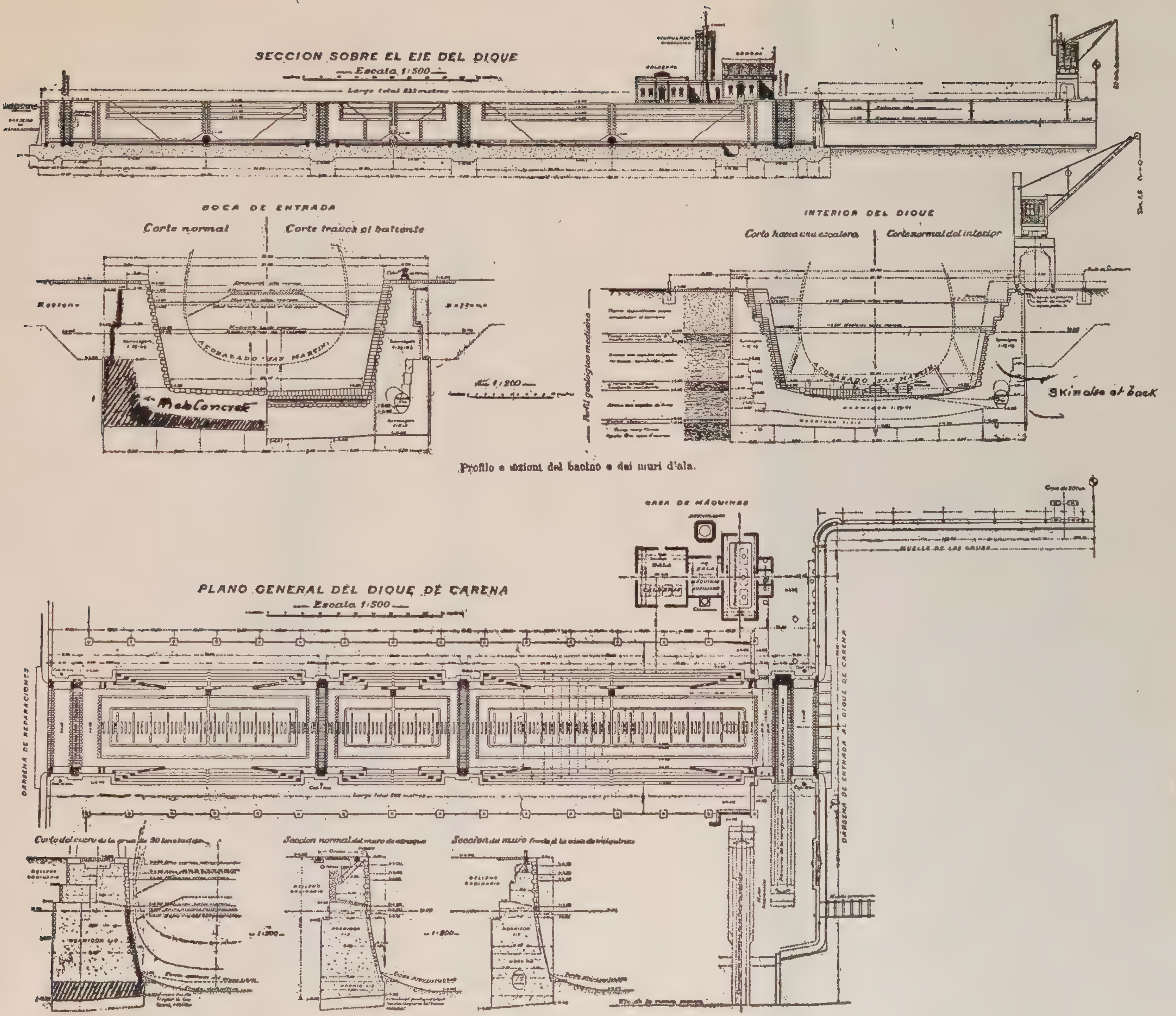

FIG. 16.—GENERAL PLAN OF DRY DOCK, ARGENTINE NAVAL STATION AT BAHIA BLANCA, ARGENTINA.

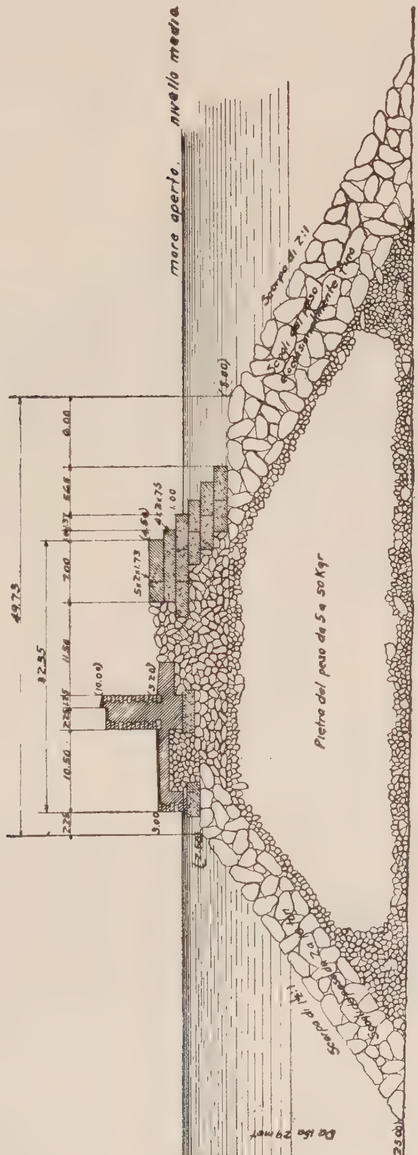

FIG. 17.—THEORETICAL SECTION OF HARBOR OF GENOA—GALLIERA MOLE. PROJECTED 1877; CONSTRUCTED 1877-78.

The great advantage of the plan which called for a rubble backing with concrete face blocks laid in regular courses over a facing laid at random was soon noticed. The close joints prevented the sea from washing through the structure and gradu-

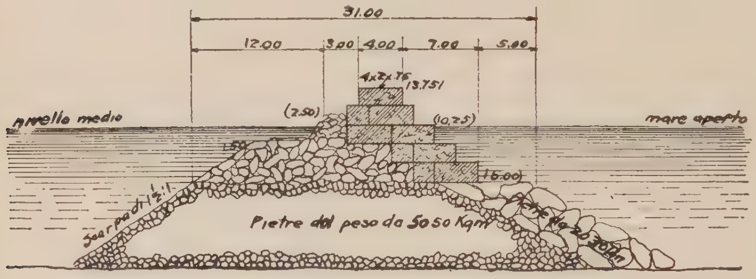

FIG. 18.—HARBOR OF GENOA—GIANO MOLE. PROJECTED 1883; CONSTRUCTED 1884-88.

ally disintegrating and wearing down the face of the blocks until finally they were washed out of the wall's face by the receding water, necessitating repair work. The wall with its face laid in regular courses is better able to resist the action of the salt

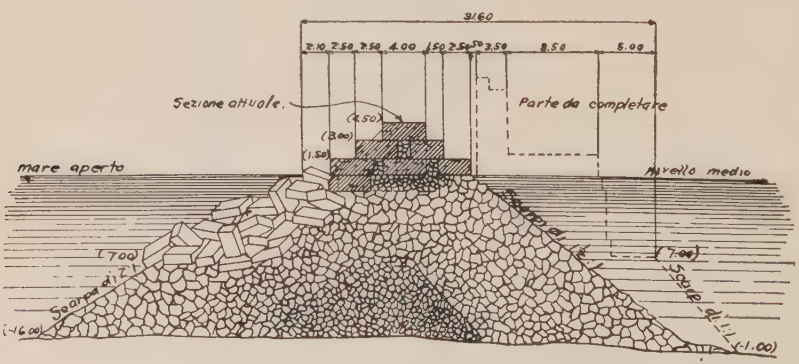

FIG. 19.—HARBOR OF CANTANIA—NEW MOLE. PROJECTED 1872; CONSTRUCTED 1873-89.

water and the repairs on same are very slight, due chiefly to the disintegration of the outer faces of those blocks, which are placed above water, and which are alternately dry and wet. Repairs are readily made by refacing the blocks with a coat of

mortar mixed 1 : 2½. The Giano Mole, Genoa, is built in accordance with these plans and although completed in 1888 has required very little repairing and the cost of maintenance of this break-

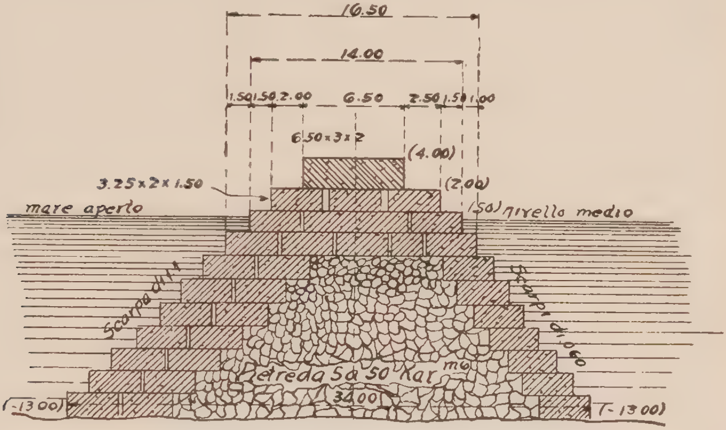

FIG. 20.—HARBOR OF LEGHORN—VEGLIAIA MOLE.

water has been very slight although it has been exposed to the heavy southeasterly gales and the huge waves rolled in by them. Puzzolana was used in the construction of this breakwater.

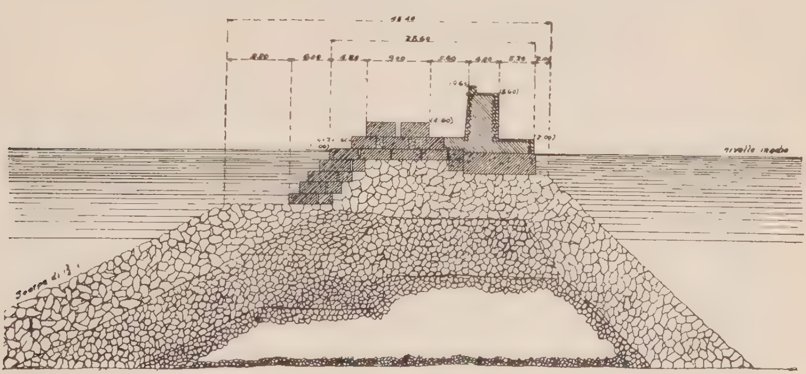

FIG. 21.—HARBOR OF NAPLES.

The Dutch have used concrete extensively in their harbor works. The concrete in all cases has worn well and they have had no trouble with their docks. An improvement in the method

of constructing their walls was the introduction of a pneumatic caisson, which enables them to cut off their piles and lay the platform and build up the concrete wall to a point above M. L. W. dry, this has proven a very satisfactory and economical method of doing the work, every step can be inspected as it progresses and the possibility of obtaining poor results eliminated, as the concrete is laid in place dry. The sea walls in

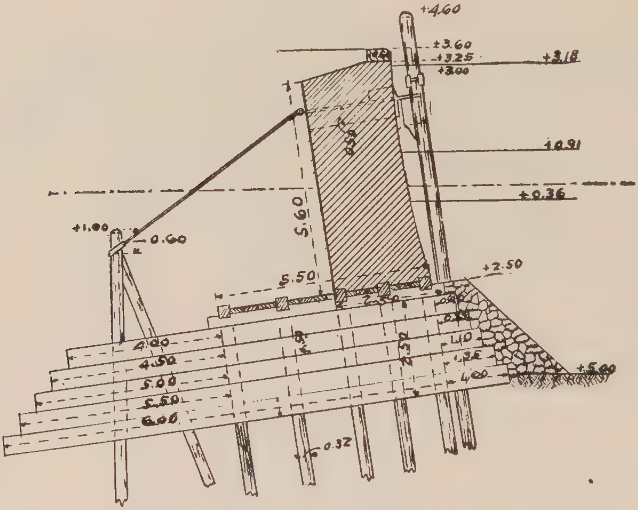

FIG. 22.—WEST SIDE OF BULKHEAD OF THE SPOORWEGHAVEN, ROTTERDAM, HOLLAND.

Holland, some of which are very old, do not give any evidence of having been affected by the salt water (Figs. 22, 23 and 24).

The Belgians in the construction of the large breakwaters at Heyst used reinforced concrete shells which were floated to place and sunk, at low tide by being filled with concrete, this avoided the use of large derricks which would probably have been wrecked by the heavy storms off that coast. This work proceeded very rapidly even under most unfavorable conditions. The Heyst breakwater was completed in 1903 and although exposed to heavy seas and to large changes in temperature is standing to-day as sound as ever.

Figs. 25 and 26 show the types of walls built for the City of Philadelphia along Delaware Avenue by George S. Webster, Chief Engineer, and J. A. Bensel, Consulting Engineer for the Girard Estate. The concrete wall in each case, from about M. L. W. up was built of concrete laid *en masse* with expansion joints every 72 ft., and although completed eleven years ago, is in splendid condition. The specifications were very strict, and supplies which did not conform to them were rejected and not used in the work. The mixture was one part Portland

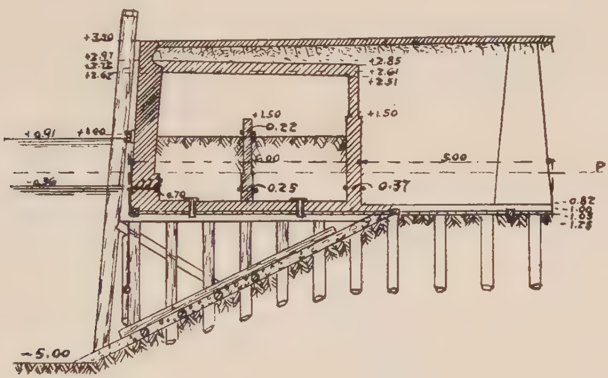

FIG. 23.—EAST SIDE OF BULKHEAD OF THE SPOORWEGHAVEN, ROTTERDAM, HOLLAND.

cement, three parts coarse sand or gravel graded from fine to coarse and screened to reject all particles greater than ¼ in. in diameter, free from loam, dust and dirt, and six parts of broken stone, clean broken granite, trap rock or other hard approved stone, crushed to pass a 2 in. ring and screened to reject all pieces less than ¼ in. in diameter. The concrete was carefully mixed and then deposited in the forms with great care, and the entire work was carried on in a first-class manner. The Portland cement was of the best quality, and was required to pass very rigid inspection, showing a tensile strength mixed 1 : 3 of 170 lbs. per sq. in. at the end of 7 days and at the end of 28 days, 240 lbs. per sq. in. At first a granolithic facing, composed of two parts Portland cement and three parts of granolithic broken

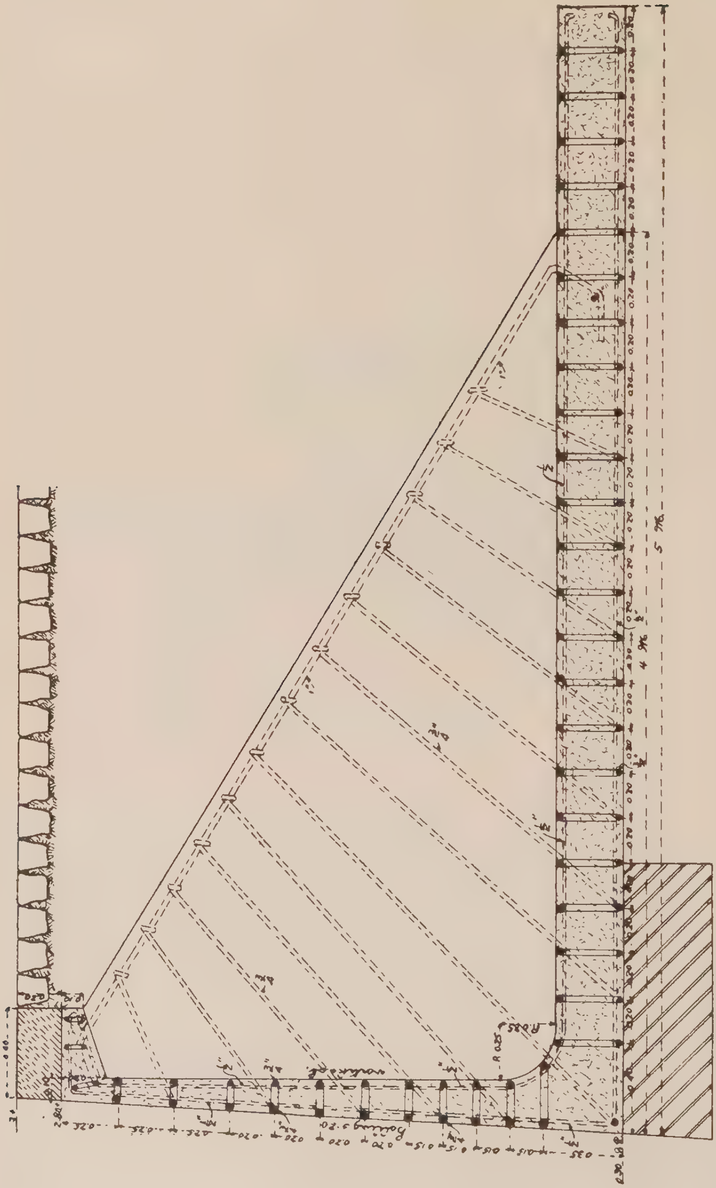

FIG. 24.—BULKHEAD OF THE SCHIEKOLD, ROTTERDAM, HOLLAND.

stone was worked in next to the form as the coarser concrete was cast, but this eventually was abandoned. The general condition of this bulkhead is good, and the entire work is a proof that carefully worked concrete will give lasting results.

Concrete has not only been used as a protection against the inroads of the sea; it has also been adopted as a protection against the ravages of the Teredo. This worm infests the waters of our entire Atlantic seaboard, south of Eastport, Maine. It is more active in the southerly regions where the water remains warm the year around, and some protection against its voracity is necessary. Creosoting was found to be fairly satisfactory, but not permanent enough, so that eventually concrete was employed as a protection against the Teredo and Limnoria.

Figs. 27 and 28 show protected pile after 5 years use. These piles had been wrapped with tar and burlap as a protection against the Teredo and Limnoria. The photograph shows very plainly the ravages of these worms in spite of this outer covering. The difficulty in finding a protection against the worms resulted in the designing of many types of concrete piles.

The United Fruit Company, having to contend with this pest, determined to put in a worm-proof dock at Bocas del Toro, Panama, so they retained Mr. T. H. Howard Barnes to design a concrete wharf. The entire superstructure was built of reinforced concrete resting on a substructure of unearthed southern pine piles, these, after they were driven to grade, were protected by 2 in. concrete shells, reinforced with 6 x 6 in. electrically welded wire mesh. The shells were built on land, were allowed to set thoroughly before being placed in the work, and were slipped over the piles to protect them. A 2 in. space was left between the piles and the shells which was afterwards filled with concrete, a rich grout being first placed in the bottom of the space and allowed to harden sufficiently to enable the water to be pumped out and the remainder of the concrete laid dry.

The dock seems to be wearing satisfactorily, although fairly large steamers land alongside, the concrete protection of the piles has not shown any signs of cracking or disintegration. Some details are shown in Fig. 29.

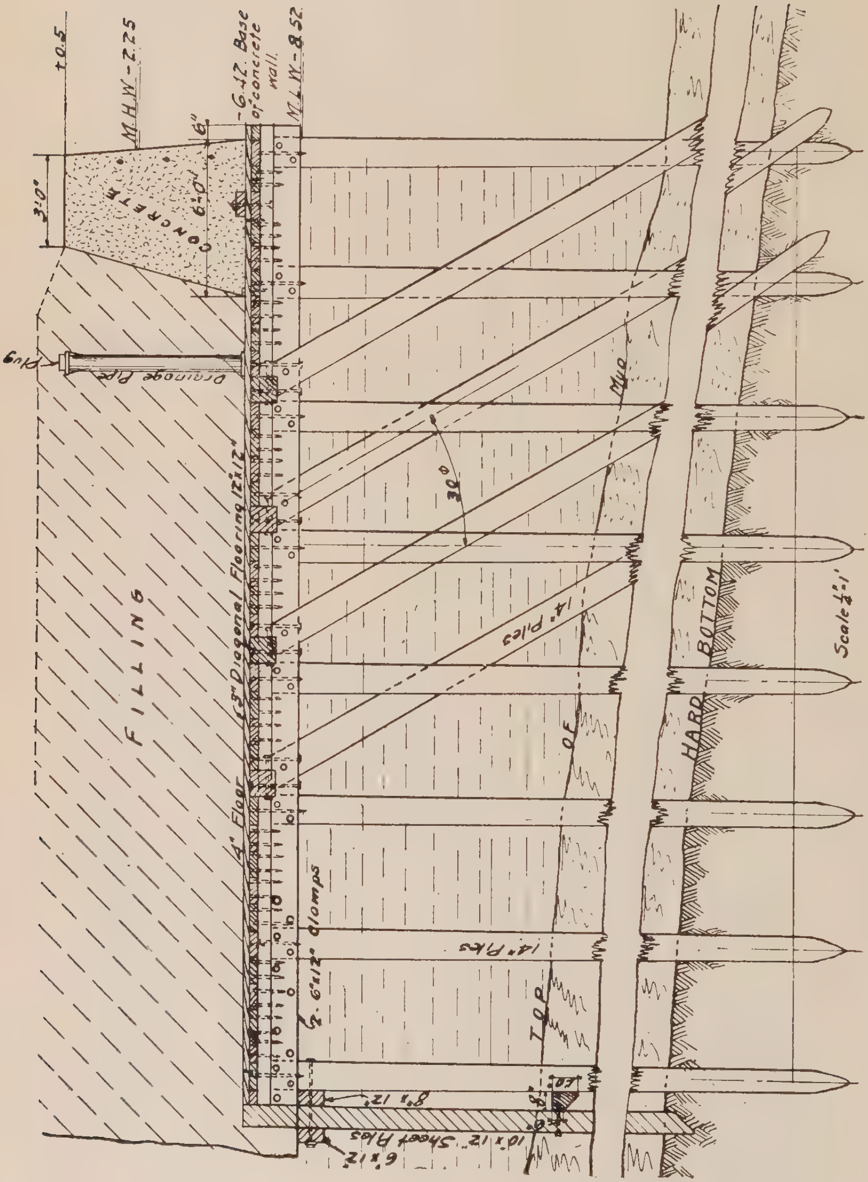

FIG. 25.—DELAWARE AVENUE BULKHEAD, PHILADELPHIA, PA.

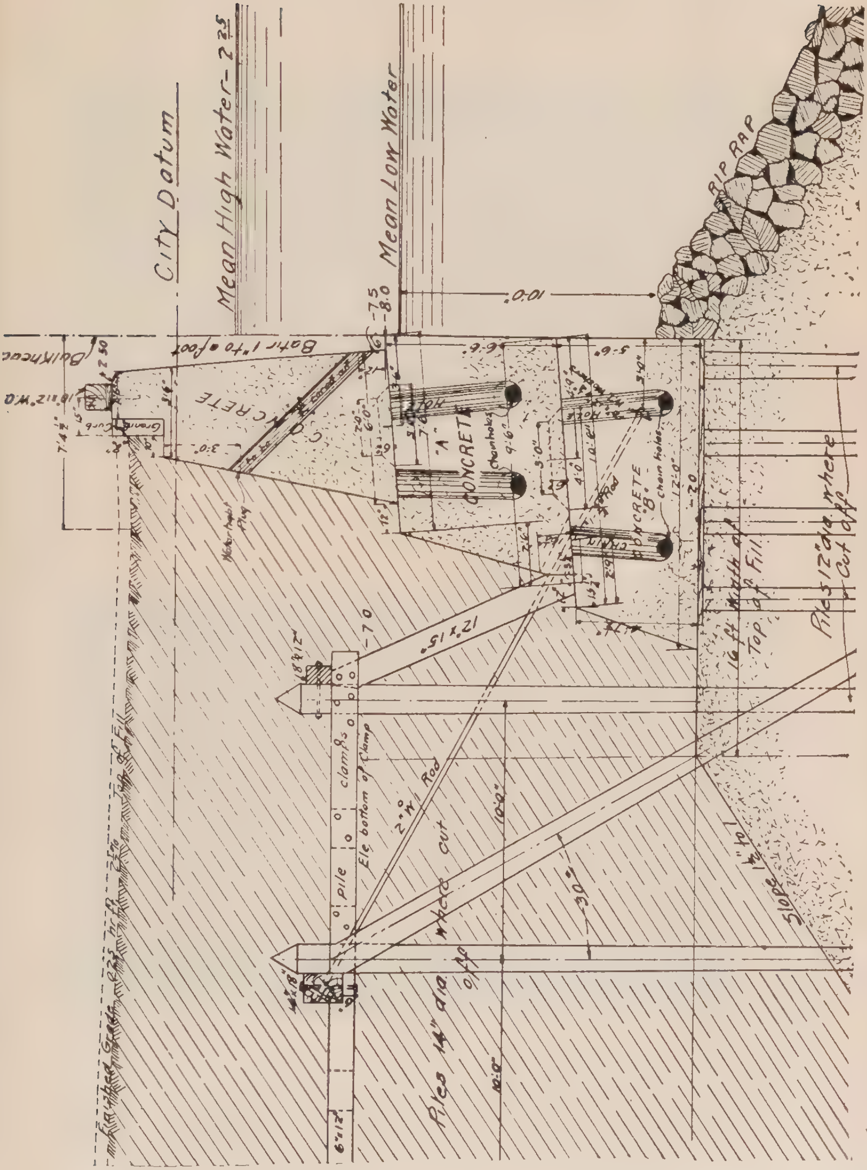

FIG. 26.—GENERAL CONCRETE SECTION OF DELAWARE AVENUE BULKHEAD FROM VINE TO SOUTH STREETS, PHILADELPHIA, PA.

Mr. J. M. Braxton, Assistant Engineer U. S. Army, designed a pile which he used in the vicinity of Jacksonville, Fla.

FIG. 27.—PILES TAKEN FROM MALLORY DOCK, KEY WEST, FLA., SHOWING ACTION OF LIMNORIA AND TEREDO IN FIVE YEARS' TIME, IN SPITE OF ORIGINAL COATING OF TAR AND BURLAP.

FIG. 28.—PILE TAKEN FROM MALLORY DOCK, KEY WEST, FLA. PILE ORIGINALLY COATED WITH TAR AND BURLAP; SHOWS ACTION OF LIMNORIA AND TEREDO IN ONLY FIVE YEARS' TIME.

The pile is composed of concrete reinforced with twisted steel rods. On the lower end it is fitted with a cast iron point (Fig. 30), the interior of which contains two ribs at right angles,

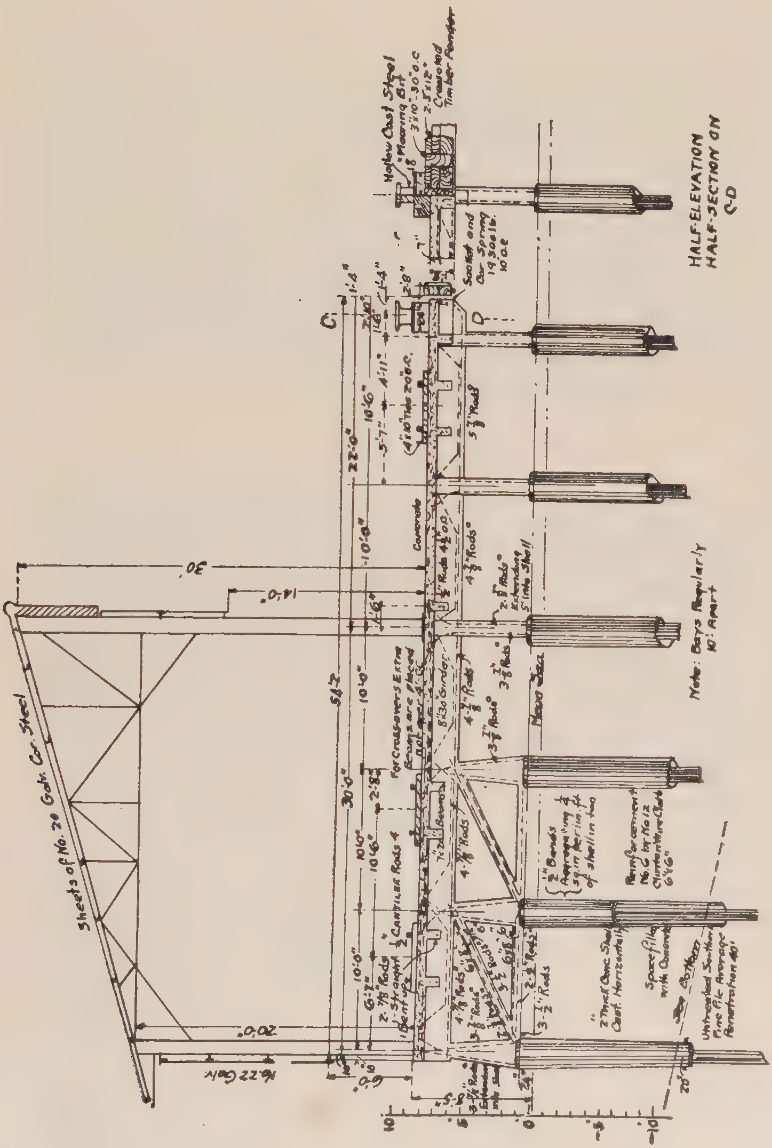

FIG. 29.—ALMIRANTE WHARF OF UNITED FRUIT COMPANY AT BOCAS DEL TORO, PANAMA.

to which the twisted steel reinforcing rods are secured. The point is so cast that it forms a shoulder of about 2 ins. greater diameter than the pile. This shoulder engages and supports a

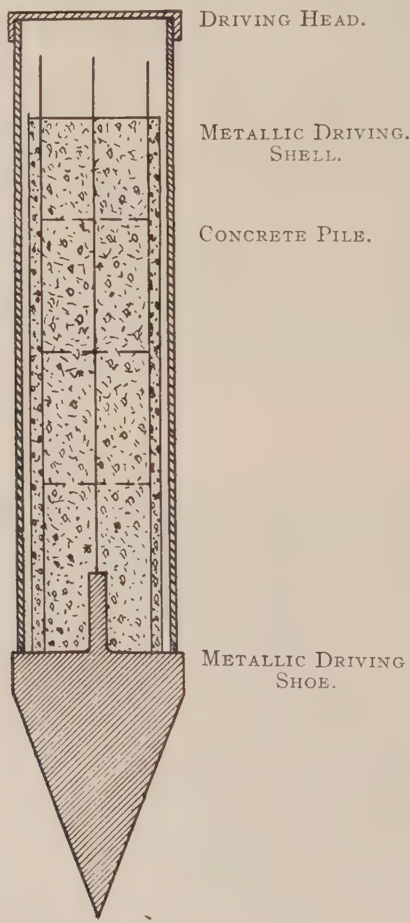

FIG. 30.—SECTION OF BRAXTON CONCRETE PILE.

wrought iron shell which is used to transmit the blows of the driving hammer directly to the point and relieving the concrete of the shock due to the hammer blows. The pile is driven as any wooden pile would be, the iron shell, however, is removed after the driving is completed.

The advantages of this pile is that as soon as driven it is capable of supporting the load or structure that is to be placed upon it, the pile is not subjected directly to the blows of the driv-

FIG. 31.—BRANTON PILES.

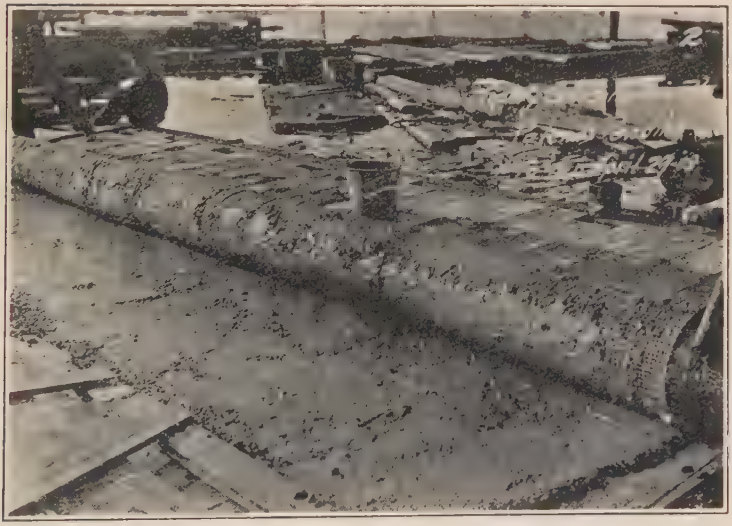

FIG. 32.—RIPLEY COMBINATION PILE.

ing hammer and it is built in a form, flat on the ground (Fig. 31). It can be made and used in any length which is obtainable in wood. In actual work at Key West this pile has been driven

two feet into the coral rock, in addition to having been driven through the overlying sand and boulders, the driving shell being easily withdrawn afterwards.

In the extensive alterations to their wharf property in Jacksonville, Fla., the Mallory Steamship Company, through their contractors, were obliged to devise some means to obviate the

TABLE I. TESTS OF COMPRESSIVE STRENGTH OF RIPLEY COMBINATION PILE.

Pile consists of a wooden core encased in reinforced concrete.

Ends of concrete casings shattered some from cutting off castings to secure as even bearings as possible.

Compressed surfaces faced with plaster of Paris to secure even bearing in testing machine.

Dimensions at small end.			Sectional area. Concrete and core at smaller end, square inches.	Ultimate Strength.	
Length, feet and inches.	Maximum Diam., inches.	Minimum Diam., inches.		Total.	Per sq. in.
19–7.7	14.65	14	153.94	480,000	3,118

Pile failed about 7½ ft. from the bottom end, opening oblique and longitudinal cracks in the concrete casing, also crushed fibers of wooden core at two ⅜ in. spikes.

Retest of section taken from upper end of first pile to determine bond between concrete and wooden core. Under a total load of 145,000 lbs. applied to the wooden core the bond between the core and concrete was disturbed, the core being forced along towards the larger end of the pile. The resistance increased to 159,000 lbs. when the core had been moved a distance of about 1½ ins. The core was pushed a distance of 8 ins. through the concrete sleeve, the test then discontinued.

After the test the concrete was removed and sixteen ⅜ in. spikes were found driven into the core to connect the wrapper.

use of wooden piling, which, despite any method of protection yet used, were rapidly destroyed by the action of the Limnoria and Teredo. Creosoting was found not to be absolutely satisfactory and they adopted the Braxton pile with very satisfactory results. These piles are also being used by the Government at Key West, Fla., in a dock designed by Captain George R. Spalding, Corps of Engineers, U. S. Army. The dock in

question is in course of construction but the piles seem to be able to withstand the severe handling they undergo, being driven two feet into the coral rock. They do not show any signs of deterioration in spite of the hard driving they have been subjected to.

John Monks and Sons of New York, the contractors of the Mallory Line Dock at Jacksonville, Fla., have used a concrete pile, designed by Mr. John W. Ripley, which can be manufactured at slight cost and as easily handled and driven as a wooden pile.

The Ripley combination pile (Fig. 32), is made by wrapping a layer of concrete around a wooden core. The concrete is first spread out on a wire mesh and the whole is attached to the core and rolled around same. The wrapper is then secured by binding wires spaced about 2 ft. centers along the pile which is then covered with a ⅛ to ¼ in. thick coating of mortar. While the piles are hardening they are wet down each day for several days after completion. Tests made at the U. S. Arsenal at Watertown, showed that the Ripley piles have great strength and a pile a little over 14 ins. in diameter and 20 ft. long tested as a long column broke at 240 tons or about 3,000 lbs. per sq. in. At Jacksonville, Fla., they were successfully driven through a fill of coral rock and dirt into the rock bottom without damaging the concrete protection. A test for bond showed the enormous strength of fifteen tons per linear foot of pipe. Table I gives the results of tests made at the United States Arsenal, Watertown, Mass.

Another pile which has been extensively used is the Chenoweth reinforced concrete pile, designed by Mr. Alexander Crawford Chenoweth* (Fig. 33). It can be manufactured without the use of forms and only requires the simplest kind of machinery in its construction. The process of manufacturing these piles consists simply in rolling a sheet of concrete spread out on a wire mesh into a cylinder about a center tube, steel bars are used as a further reinforcement. The pile after having been rolled is tied at frequent intervals with wire to hold the roll

*For further description and illustrations of Chenoweth and other types of piles, see *Proceedings*, Vol. V, p. 300.—ED.

together while the concrete is setting. They can be made in almost any length, 80 ft. long, the longest made thus far. When used in salt water a proportion of the concrete of one part of cement, two parts of sand and three parts of gravel, according to Mr. Chenoweth, giving the best results and the required density for piles to be used under such conditions.

The docks and wharves of the Havana Central Railway at Muelle de Luz, Havana, Cuba, are founded on Chenoweth

TABLE II. SOME GENERAL PARTICULARS OF COMPRESSION TESTS OF CHENOWETH REINFORCED CONCRETE PILES, AGE AT TEST ABOUT 3½ MONTHS; MADE MARCH 8 TO 12, 1909, PROFESSOR A. N. TALBOT, UNIVERSITY OF ILLINOIS, ILL.

Reference No.	Length, ft. and ins.	Approximate Average, diameter, ins.	Gross Area, sq. ins.	Ultimate Load, lbs.	Crushing Weight, in tons.	Crushing Weight of a wooden pile under same conditions unsupported, in tons.
1......	24–4	14.5	165	280,000	140	17
2......	20–5	15.3	183	260,000	130	to
3......	16–0	14.1	156	279,000	139	20

piles, which are wearing well and do not show any signs of deterioration in the dirty waters of that harbor.

Several tests of this pile were made at the University of Illinois and the results obtained are given in Table II.

The Japanese have successfully used concrete in their harbor works and report very good results. They use Japanese cement almost entirely and by careful manipulation and placing of the concrete the walls withstand the action of the sea water without any reported failures.

The proposed pier now being constructed at Kobé, Japan, K. Morigaki, Chief Engineer, is shown in Fig. 34.

The geological formation of the harbor of Kobé is similar to that of the North River, New York, both have a very deep underlying bed of silt, hard bottom is found at such depths that artificial foundations have to be constructed. The bottom was dredged to a depth of 42 ft. below M. L. W. forming a trench 58 ft. wide on the bottom the length of the wall. This was

filled with sand to 34 ft., and finally brought to grade 30 ft. with an embankment of gravel and rip-rap carefully leveled off on top.

The wall proper rests on ferro-concrete caissons. These

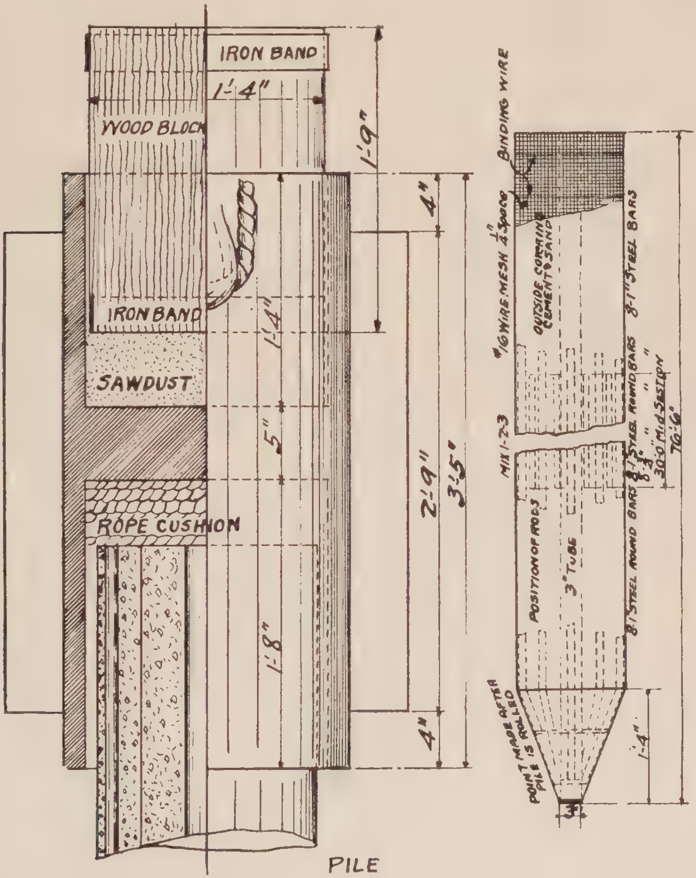

FIG. 33.—CHENOWETH CONCRETE PILE.

shells, weighing from 1,600 to 2,200 tons, are built on the land and after being allowed to season for 2 months are floated to place by means of a specially designed depositing dock. A longitudinal diaphragm divides each caisson into two parts, the front half of which is filled with concrete and the rear portion

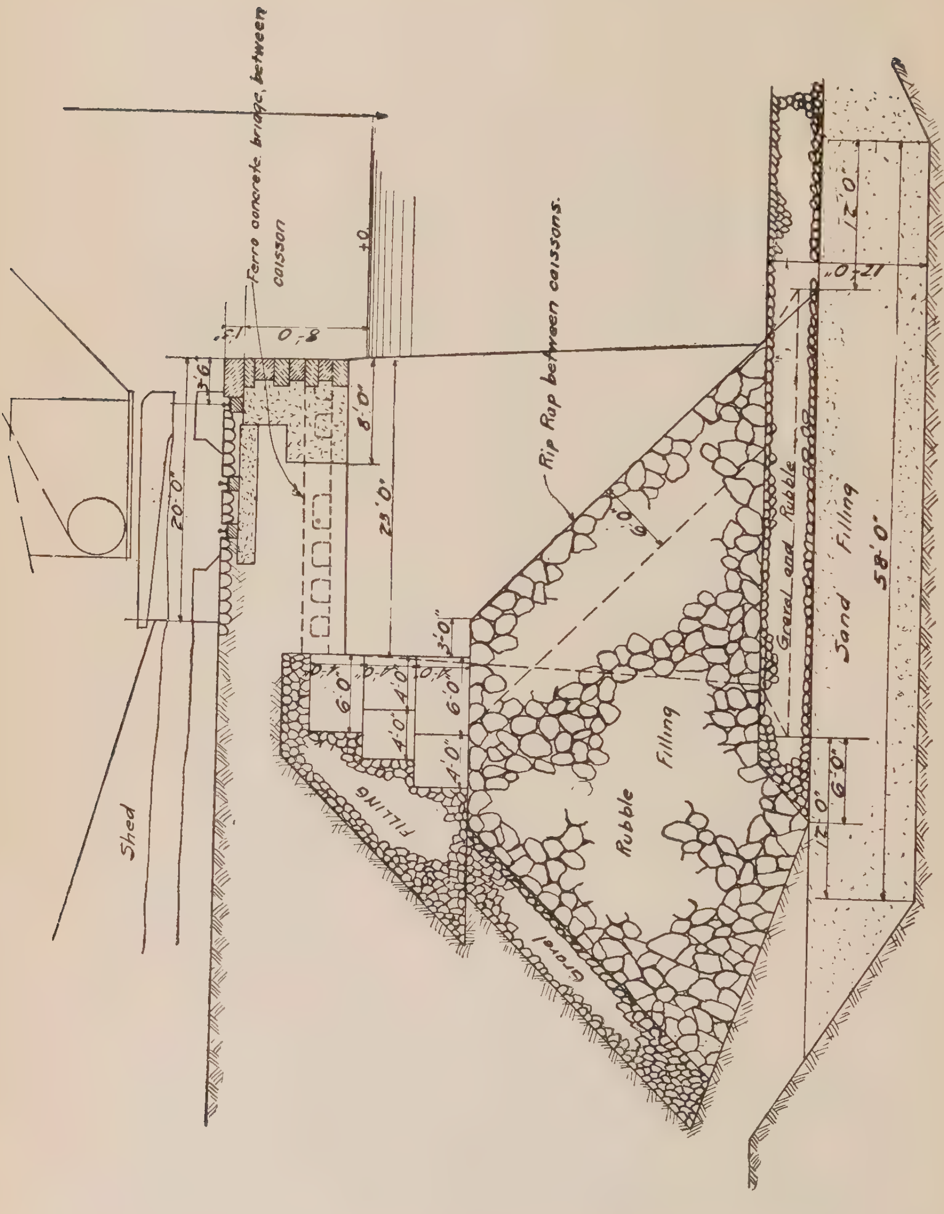

FIG. 34.—QUAY WALL, KOBE, JAPAN.

with sand and gravel. This style of quay wall has been successfully used by the engineers of Rotterdam, Holland, and proven to be economical. The wall is then built up to the proper grade with concrete and granite as shown. A rip-rap embankment is deposited in the rear and between the caissons and brought to such a height that the toe of this bank will not project beyond the toe of the caisson. The work is not completed as yet, but so far seems to be satisfactory, some settlement has been observed, as would be expected, but nothing very serious, the entire structure will be built of concrete made with Japanese cement.

Although the majority of the work carried on in concrete have been successful, a number of failures are recorded. A most notable failure due to the deterioration of the concrete is the Graving Dock at Aberdeen, Scotland. This dock which was built of concrete, was opened in 1885 and immediately showed signs of leaks, two years later, in 1887, the leakage was so bad that Mr. William Smith was called in to make a report on the condition of the dock. Samples were cut out of the concrete and sent to Professor Brazier of Aberdeen University to analyze. This was done and it was found that the deterioration was due to the chemical action of the salt water on the cement. Professor Brazier says: "The analyses of the series of decomposed cement show a remarkable difference to the original cement, inasmuch as that in all these samples there is found a large quantity of magnesia and a large proportion of lime, in the form of carbonate. I believe this alteration is brought about entirely by the action of the salt water upon the cement. There is no other source for either the magnesia or the carbolic acid."

Mr. Philip J. Mersent, was called as a consulting engineer to report, and as a result of his examination reported* that as near as he could determine the deterioration existed chiefly in those sections where the portions of sand to cement was three parts sand to one part of cement or even more. This high ratio of sand gave a very porous concrete. The mortar layer plastered on the surface of the concrete and mixed one part of cement

* *Proc. Inst. C. E.*, Vol. CVII.

to one and one-half parts of sand had as a rule hardened thoroughly and was in very good condition, as was also the concrete which was mixed one part cement, two parts of sand and four parts of stone. The concrete must be impermeable to water if it is to have any life at all and as long as it is, it will last indefinitely. Permeable concrete soon deteriorates and rapidly goes to pieces, softening and eventually crumbling away. Mr. J. W. Sandeman, as well as Com. Luigi Luiggi, both advocate an impermeable concrete.

Mr. Sandeman in his paper on "Action of Salt Water Upon Concrete," states that concrete must be impervious if it is to last any length of time, and the maximum proportion of the sand in the mortar must not be more than twice that of the cement, the mortar must exceed the maximum voids in the aggregate so as to thoroughly cover the aggregate as well as fill all the voids. Concrete proportioned as above will give satisfactory results, provided the materials are of the best quality of their respective kinds. The concrete must be impermeable if it is to be used under or in salt water. He found that a concrete made with mortar composed of cement and fairly coarse sand gave better results and a more impermeable concrete than one mixed with a larger proportion of fine sand. Bearing this in mind, Com. Luigi Luiggi was able to build a perfectly tight dry dock at Bahia Blanca.

Concrete to be used in water, and salt water especially, must be impermeable or it otherwise will soon be destroyed by the action of the chemicals in the water. The cement must be of the best quality and be thoroughly analyzed, tested and inspected before using. The sand must be a clean sharp sand free from loam, and all vegetable and foreign matters. The stone must be a clean sound stone, or a clean gravel of the proper size, Great care must be taken with the mixing and the placing of the concrete and it this is done, there is no reason why a concrete structure should not be as lasting as one of stone.

The great ease with which concrete structures can be built, the small cost of annual maintenance and the almost indestructibility of the structure should recommend the use of this material in perference to others and more than overcome the greater

initial cost. Eliminating such charges as would be common to all kinds of quay walls, such as backfilling, dredging and paving, a concrete wall founded on short wooden piles and hard bottom and faced with granite from about mean low water up would cost about four times as much as a wooden crib bulkhead. The cost of maintenance of the masonry wall would be practically nothing and its life unlimited while the crib bulkhead, would require rebuilding every fifteen years from M. L. W. up, and the annual repairs to same would be considerable. This comparison of construction is based on prices as they were ten years ago. At the present time the cost of lumber has nearly doubled while the prices of cement, broken stone and sand have practically remained stationary, so that to-day the initial cost of the concrete structure would not be much more than two to two and one-half times that of the wooden bulkhead or dock.

The United States having considered that it had an inexhaustible supply of lumber has not developed the use of concrete in its harbor works to the same extent as other nations who are less fortunate in their natural resources. However, the constant drain made on the eastern pine forests has practically exhausted them and the great advance in prices has obliged the engineer to search for some material to replace wood and this will naturally cause them to turn to concrete.

THE ESSENTIAL QUALITIES AND THE APPLICATION OF CONCRETE TO TIMBER STRUCTURES IN SEA WATER FOR THE PURPOSE OF INCREASING THEIR PERMANENCY.

By Ralph Barker.*

The principal enemies of timber structures in sea water are the Limnoria and the Teredo.

The Limnoria works at the surface of the water and makes his attack on the outside of the timber and does not enter and live in it. Consequently, when a pile has been exposed to this insect a sufficient length of time, it has the appearance, between high and low water, of an hour glass, the narrowest part being at mean tide level where it has been exposed the greater length of time. The Limnoria does not destroy timber as fast as the Teredo, and its sphere of action is not so great. Also, when a pile is eaten enough by the Limnoria to impair its strength, the fact is obvious, which is not true of the Teredo.

The Teredo, the most destructive foe to timber work in sea water, works between the mud line and mean low water. He enters the timber in the form of a minute worm, making a hole in the shell of the timber no larger than a pin. After entering the wood he grows rapidly, boring his way rapidly to the grain of the wood, the size of the hole rapidly increasing to accommodate his increasing size, until it is frequently half an inch in diameter. The small hole through which the borer entered remains at its original small size and the timber, if not otherwise attacked, appears as sound as ever.

This insidious enemy infests the waters of the Pacific Coast in enormous numbers, and is the most destructive, by far, with which we have to contend. Untreated fir piles in the Bay of San Francisco have been so riddled by the Teredo in eight months

*Assistant State Engineer, San Francisco, Cal

that their bearing capacity is practically nil, and a very slight transverse stress would break them.

It is plain from the foregoing that the use of untreated timber for the support of structures in sea water infested with these marine borers is absolutely out of the question, except for extremely temporary work.

There are several methods for treating timber for its preservation which may be divided into two classes:

1. The impregnation of the wood with some chemical which is distasteful to the insects which attack it.

2. The placing of some substance around the timber which is impervious to the attack of such insects.

The first method is very largely in vogue here, but is open to many objections which I will not enumerate. Its principal recommendation is its cheapness. The latter method is coming rapidly into use, and as concrete is the cheapest, most available, and most readily applied material, it will probably supercede all others.

The one great requisite essential for a hydraulic cement, regardless of the special purpose for which it is to be used, and therefore embracing its use in ocean waters, is that when properly handled it shall form a strong and permanent cementive bond; that when crystallized and hardened it shall become an enduring and resistant matrix for the inert particles of sand and stone, together with which it forms an artificial conglomerate stone. As to the type of hydraulic cement best fitted for use to secure this general essential quality of enduring cementive strength under the conditions imposed, the subject has been, and still is, one of considerable question.

The two destructive influences most necessary to provide against are

1. The peculiar chemical disintegrating action of the magnesium sulphate contents of ocean water upon the aluminum compounds in the cement.

2. The physical wear of the surface of concrete thus chemically affected and softened by the abrasive action of the water of "The ever-restless sea," and the greater or less content of sand which it may carry with it.

Naturally the first endeavor has been to produce a cement so constituted that the chemical action of the sea water should be reduced to a minimum. Basing their work upon the theory that the aluminum content of a cement could for fluxing purposes in manufacture, be replaced by iron which is not affected deleteriously by magnesium sulphate, German makers have placed upon the market an "Iron Ore Cement" or "Erz-Cement" as it is called. Accelerated tests of this material have been made by the makers, by immersion of mortar blocks in sea water of

FIG. I.—PIER UNDER CONSTRUCTION.

intensified strength. These tests as reported seem to prove that as compared with Portland cement of the usual character, under the same conditions, the Iron Ore cement blocks withstood the chemical action of the sea water very much more successfully.

Tests of imported Iron Ore cement are now under way in San Francisco, comparing it under exactly similar conditions with a standard brand of Portland cement made in California. These tests have been running for only six months up to the time of the present writing, and perhaps may on that account be not exactly conclusive. The results of these tests as far as carried out are given in Table I.

Another series of systematic experiments made with the purpose of determining the question of a resistant cement for sea water use, were begun 14 or 15 years ago by the German Government at the instigation of Puzzolan-Portland cement manufacturers.

Puzzolan-Portland is a mixture of either natural puzzolan, (a volcanic ash) and Portland cement; or of artificial puzzolan, (blast furnace slag of certain chemical composition) and Portland cement. Depending upon the chemical composition of the puzzolan, the mixture contains from 30 to 60 per cent. of puzzolan, and from 50 to 70 per cent. of Portland. The mixture can be made after pulverization, if necessary, by the engineer or contractor on the work. Preferably, however, the ball-mill product of both ingredients are pulverized together in the tube or other finishing mill at the cement factory.

TABLE I.—COMPARISON OF TENSILE TESTS, IRON ORE CEMENT AND PORTLAND CEMENT, STORED IN FRESH WATER AND IN SEA WATER OF FIVE TIMES NORMAL STRENGTH.

	Tensile Strength, lbs. per sq. in.	
	Iron Ore Cement.	Portland Cement.
Stored in fresh water.		
30 days neat	653	704
1 to 3 sand	359	396
90 days neat	825	725
1 to 3 sand	499	465
180 days neat	808	801
1 to 3 sand	526	491
Stored in sea water, five times normal strength.		
30 days neat	853	863
1 to 3 sand	343	441
90 days neat	981	1019
1 to 3 sand	493	508
180 days neat	1026	1160
1 to 3 sand	486	479

The result of the German Government experiments at the Royal Testing Station at Berlin, carried through a fairly long series of years (the five years' tests have recently been completed), seem to prove rather conclusively that under exactly similar conditions of mixture and subsequent immersion in sea water, the Puzzolan-Portland concretes showed higher strength

than the pure Portland concrete in both tensile and compression tests, and that the Puzzolan-Portland concrete blocks with which the tests were made, held their original form in much better condition than did the blocks of concrete made with pure Portland, the latter having very visibly suffered from chemical action and abrasion in the sea water. As to the comparative economical value of Puzzolan-Portland and pure Portland in the rich concretes made for the German Government tests in sea water, the results seemed to prove that a barrel of the Puzzolan-Portland was equal in producing resistance to the action of sea water to two barrels of the pure Portland.

An examination of the two types of concrete blocks used in these experiments also seemed to prove true the theory of Dr. Michaelis that the hardening of the Portland cement in the Puzzolan-Portland mixture was accompanied by a chemical decomposition in which a portion of the combined lime in the pulverized clinker was transformed into lime hydrate, and this latter, in some measure at least, made another combination with the pulverized puzzolan, producing a puzzolan hydraulic cement, invulnerable to sea water. Final corroboration of these sea water experiments and their results in this country will be awaited with great interest. At the present time, however, Puzzolan-Portland is not manufactured in the United States, although deposits of properly constituted volcanic ash, suitable for the purpose undoubtedly exist in numerous parts of the country.

With the materials heretofore at his command, the American engineer has been principally confined in sea water concrete construction to the use of Portland cement. Although disastrous disintegration has occurred in some instances, it is nevertheless true that the great mass of well constructed Portland cement concrete in sea water has served its purpose satisfactorily. Portland cement concrete has the power of armoring itself against the action of the magnesium sulphates of the sea water by the formation on its exposed surfaces of a skin or film of lime carbonate. In comparatively still waters this appears to constitute a very effective protection. In case of violent or continued abrasion of water and sand it is naturally less effective, and in exceptional cases has no opportunity to form. In these cases the calcium hydrate

set free by the decomposition incident to the hardening of the Portland cement, is washed away, leaving voids for the further inroads of the deleterious chemicals contained in the sea waters.

FIG. 2.—FORMS REMOVED FROM PILE IN FOREGROUND.

In selecting a Portland cement for marine construction, for at present the American engineer is in large measure confined to choice of cements of the common type for work of this class, the ordinary precautions taken to secure a trustworthy material

(*i. e.*, careful and accurate sampling and testing) are absolutely essential. The Standard Specifications of the American Society for Testing Materials* indicate the requirements admirably in the main. That the cement must be sound goes without saying. Since only the very finest portion, the "float" of the Portland has

TABLE II.—COMPARATIVE TENSILE TESTS OF TWO STANDARD PORTLAND CEMENTS, STORED IN OCEAN AND IN FRESH WATER.

	Tensile Strength, lbs. per sq. in.	
	Ocean Water.	Fresh Water.
Brand A.		
30 days neat	1132	844
1 to 3 sand	522	468
90 days neat	1097	762
1 to 3 sand	540	537
180 days neat	1065	737
1 to 3 sand	521	549
Brand B.		
30 days neat	1119	827
1 to 3 sand	366	354
90 days neat	1203	733
1 to 3 sand	385	415
180 days neat	1113	823
1 to 3 sand	449	474

TABLE III.—CHEMICAL ANALYSES OF ABOVE PORTLAND CEMENTS.

	Brand A.	Brand B.
Silica (SiO_2)	21.62	21.52
Iron (Fe_2O_3)	2.15	3.57
Alumina (Al_2O_3)	6.75	7.05
Lime (CaO)	63.80	62.00
Magnesia (MgO)	1.94	1.29
Sulphuric anhydride (SO_3)	1.17	1.37
Ignition loss	2.20	2.05

cementive value, fine pulverization is essential, and a matter of much economical moment. Too slow a setting is to be avoided, and a rapid permanent hardening is of value. These, however, it is unwise to secure by the use of cements high in aluminum, since it is the aluminate content that is most vulnerable to the chemical attack of sea water.

That it is possible to secure a rapidly hardening cement not

* See Standard No. 1, of *National Association of Cement Users*.—ED.

unduly high in aluminum content is evidenced by the tests of two brands of Portland cement made in the State of California with chemical analysis of the cement thus tested, see Tables II and III.

Methods of Application.

Since the Teredo works from the mud line to low water, and the Limnoria from low water to high water, it is necessary in order to insure immunity from these pests, to protect our timber from the mud line to high water mark. As the mud line is a somewhat varying factor it is very desirable to extend the covering to a material which is certain not to be affected by any of the influences it may be subjected to, or in other words, to a sufficient depth to preclude the possibility of the unprotected portion of the timber becoming exposed.

Three methods have been used extensively in the San Francisco harbor for applying concrete to piles for their protection from marine insects and borers. Two of these methods are applicable only to new structures, before the superstructure is in place, while the third may be applied to the piles at any time.

First Method.—This method covers the use of a metal or wooden cylinder around the pile and filling same with concrete. This method was first employed in 1894. Steel cylinders 3 ft. 6 ins. in diameter were used around a cluster of 3 piles. First the piles were driven in the proper locations, then the mud removed from inside the cylinder to a depth specified. This depth is governed by conditions and is usually about 30 ft. below low water. Then concrete, which is sewn up in loose mesh burlap sacks, is placed in the cylinders in sufficient quantity to fill it nearly to low water line. This was allowed to set and the water is then pumped out and the balance of the cylinder filled with loose concrete. This method was later cheapened by the substitution of wooden stave cylinders for the steel cylinders. The most recent practice in this method is to use a cylinder only 2 ft. in diameter, having a cast iron shoe in its bottom which fits as close as possible around a single pile. Rope grummets are placed around the pile and as the cylinder is driven, the grummet is forced tightly between the casting and the pile thus making a

tight joint which excludes the mud and water to a very great extent. What mud and water may have gotten inside the cylinder is then removed by a jet pump and the cylinder is filled with concrete, same being reinforced with vertical rods held in place by horizontal bands. The latter practice gives the best results, as the placing of concrete under water, even in sacks, is almost certain to cause a separation of the ingredients. The wooden cylinder is eaten away by the marine insects in a short time and if the concrete is not perfectly sound, the Teredo enters and destroys the piles.

Second Method.—This consists of using a concrete cylinder of about 24 ins. external diameter and 2¾ ins. thick, heavily reinforced. The length of the cylinder is governed by conditions the same as the wooden cylinder above described, the longest used here being 34 ft. The cylinder is driven around the pile, pumped out, and filled with concrete in precisely the same manner as the small wooden cylinders are used. This method gives very good results, as the outer 2¾ ins. of concrete of the finished job is made on the surface where it can be examined and rejected if defects appear.

Third Method.—This method differs essentially from the foregoing, and can be applied to an old structure without removing the top work. It consists of the use of a sheet metal form having a diameter of about 8 ins. greater than the pile to be treated, same being made around the pile in short lengths. The bottom of the first form applied to the pile is equipped with a diaphragm, which fits closely around the pile and accommodates itself to its decreasing size. The form is placed around the pile and has attached to it wire ropes from a windless on the floor of the structure. Then a cylinder of reinforcing material is placed inside the form and it is filled with concrete. This section is then lowered into the water sufficiently to allow the next section to be constructed around the pile and fastened to the one already filled. The process is continued until the first section comes to rest in the bottom of the bay. In ordinary mud the weight of the column of concrete will force it down into the bottom a sufficient distance to insure protection.

All three of these methods give very good results. The

last mentioned is the cheapest, but when it is used the pile it protects must extend up to and support the superstructure. In the other two methods the pile may be cut off at low water line, and the balance of the support made a reinforced concrete pillar, getting its lateral strength from the reinforcing bars which may be made continuous for the full length of the concrete casing.

DISCUSSION.

Mr. Chapman.

MR. CLOYD M. CHAPMAN.—We had an experience in Florida a year ago where piles made according to one of the methods just described failed, but I doubt if it failed through any fault of the method used. It was an application of the split interlocking pipe method. The two halves of the pipe were put together over the piles, leaving an annular space of about 4 ins. around the pile, which was filled with sand. The split pipes went to pieces in a very few months—it may have been weeks—and crumbled in parts and fell off. On examination, it was found that the pipes had been made of sand and cement only, no coarse aggregates being used. The sand was taken from the beach at the point where the pier was constructed, and a visual examination showed apparently few pieces of shells. It was found, however, that between two sizes of screens apparently 75 per cent. of the material was broken shells, and approximately 10 or 12 per cent. of the tested material was sea shells, which probably caused the deterioration of the concrete and the crumbling of the pipe.

Mr. Mensch.

MR. L. J. MENSCH.—I think probably Mr. Barker describes the piles I built for the San Francisco Harbor, which not only preserved the wooden pile, but also increased their carrying capacity to possibly twice the amount. They consisted of two concrete shells from 2 to 2½ ins. thick and in lengths of from 18 to 60 ft. The wooden pile was driven first and then the concrete shell slid over it and driven, forming another pile around the first pile. Then the bottom was sealed and the water pumped out and filled with concrete. Tests made of such piles showed a carrying capacity of 70 tons without any settlement. The piles were located in the mouth of the San Francisco Harbor, which consists in many places of very bad ground to a depth of 80 to 100 ft.

THE EFFICIENCY AND COST OF CONCRETE FOR THE PRESERVATION OF PILES EXPOSED TO SEA WATER.

By C. C. Horton.*

It has long been the aim of engineers and builders to find some method of treating or protecting wooden piles or other wood structures from the destructive attack of marine borers, of which the Teredo and the Limnoria are the chief representatives. Many methods have been tried, and success more or less marked has attended some of them, the principal methods being the chemical treatment of the wood fiber and the mechanical protection of the pile or timber by a protective covering of metal, treated wood or concrete. However, we are only interested in the application of concrete or cement and will pass over the other methods with but brief mention.

Under the head of chemical treatment creosote should be given first place, which proves very effective until by abrasion or dissolution the pile loses its sheath of impregnated creosote and becomes open to attack by the destructive ship worm. A pile so treated is effective for approximately 15 years, if it has received no mechanical injury to split or otherwise damage it. The metal-coated pile, as well as those covered by asphaltic compositions, are open to the same objections as the creosoted pile, but also have the added drawback of a still shorter life.

With this brief review of older methods, we will now consider the concrete covering of wooden piles, of which there are quite a variety. Several of those more or less practical will be described, classified under *A, B, C* and *D,* merely to distinguish them and not according to their relative merits.

Class A. A wooden pile covered with a jacket of concrete, made by placing a mold around the pile and filling with concrete reinforced with steel or not, applied before driving. This makes a pile which can be inspected without trouble, but has the draw-

* Healy-Tibbits Construction Company, San Francisco, Cal.

back in that it is heavy and difficult to handle and drive, and will sink, presenting the same difficulty as a solid concrete pile in this respect. Furthermore, the same precaution must be observed in driving it as in the purely concrete pile. It is difficult to give exact costs as these will vary with the size of the pile, the length covered on each, the varying cost of materials, the proportion used in the concrete, the use or omission of reinforcing, cost of labor, etc. Relative costs of the several methods will be given in conclusion, so that a comparison of the various classes may be made.

Class B. This class includes piles covered after they have been driven and before the superstructure has been built. The covering is applied by lowering over the pile a continuous concrete wood or steel jacket, so proportioned as to leave an annular space between the pile and jacket or from 2 to 4 ins., preferably the latter. This space is then pumped out and filled with concrete.

This method presents some difficulties where deep water is encountered, due to the liability of the jacket to collapse, if built of wood or steel. Furthermore, it is difficult to exclude mud and water if the sea bottom is soft or the casing is not perfectly tight. It is sometimes found necessary to seal the bottom with cement and allow it to set before pumping out the annular space. This should be done as thoroughly as possible for the best results.

Class C. This is a modification of class B in that the same type of jacket is used, with the exception that it is sectional and in two parts to admit of application to piles under existing wharves or where the superstructure is in place. A tile jacket is sometimes used in addition to the others of class B.

The jacket is applied by placing the sections around the pile and lowered by suitable means, section by section, until the submerged portion of the pile is covered and sufficient penetration is obtained into the sea bottom. The annular space is then filled with concrete without first pumping out the sea water. With this style of construction, it is impossible to exclude the water and mud, which is a serious drawback. The concrete is liable to be of inferior quality, especially at the bottom, the very point that should be made the most impregnable, the mud line being the principal point of attack of that most destructive of wood borers, the Teredo.

Class D. This is a class distinctly by itself and is of more recent origin than any of the previously described methods of armoring. It consists of a light steel sectional jacket, fitted at the bottom with a self-adjusting diaphragm, made to accommodate itself to the irregularities of the pile. The method of procedure is to fit the bottom section containing the diaphragm around the pile and fill with concrete, the section being suspended from above, usually by winches. The first section is then lowered sufficiently to permit the addition of another section, which is filled with concrete; this is repeated until the submerged portion of the pile is covered and the desired penetration is obtained into the sea bottom. The annular space between the pile and the jacket should be at least 4 ins., and in large piles of say 18 to 20 ins. diameter, 5 or 6 ins.

This method renders the concreting of piles very simple and effective and obviates the principal difficulties of the three other classes of covering. It is especially adapted to the repair of old wharves, badly eaten with either the Teredo or Limnoria. The San Francisco Harbor Board has adopted this latter method for the repair of their old wharves, and finds it economical, easily applied and durable. Classes *A* and *B* are not suitable for the repair of old wharves, the expense being prohibitive. Between class *C* and *D*, the latter may be applied for approximately 20 per cent. less per lineal foot than the former.

For new work, classes *A*, *B* and *C* would cost approximately the same, with a slight possible advantage in favor of class *A*. Class *D* may be applied to new construction more cheaply than on repair work, and would run 20 to 25 per cent. cheaper than any of the other methods.

The San Francisco Harbor Board is paying $1.55 per ft. for class *D* work on all sizes of piles. This includes profit and royalty, the actual cost ranging from $1.00 to $1.85 per lineal foot.

From the foregoing, it will be seen that concrete is adaptable to the protection of wooden piles in marine construction and is the only method giving permanent results and at the same time gives to the structure greater strength and rigidity.

RESULTS OF EXPERIMENTS UPON EFFECT OF SEA WATER ON THE TENSILE STRENGTH OF VARIOUS MIXTURES OF CEMENT AND SAND.

By Cloyd M. Chapman.*

Of the many theories and opinions now advanced to explain the change which takes place in concrete when exposed to sea water, the most plausible are those which attribute the action to a slow solution by the water of some constituent of the cement or a slow deposition in the concrete of some constituent of the sea water, or both. But these theories are necessarily based on the assumption that water enters and leaves the concrete or percolates through it, carrying something with it or leaving something behind. Put in waterproof concrete and the percolation will stop. Stop the percolation and the action will stop, and the concrete will remain unaffected.

To gather data upon this subject, the Aberthaw Construction Company of Boston, have prepared a series of exposure tests and placed them in sea water at the Charlestown Navy Yard. These tests consist of twenty-four concrete columns 16 x 16 ins. and 16 ft. long, so suspended from a dock that their lower extremity is always immersed in sea water, being below extreme low tide, while their tops are always above high tide. These columns are made of varying portions of cement, with various aggregates, mixed both wet and dry, and with and without waterproofing ingredients added. These tests should be watched with interest by those having to do with concrete in salt water.

In order to get more light on the effect of sea water upon concrete, Westinghouse, Church, Kerr and Company of New York, made a series of experiments upon the tensile strength of cement mortar immersed for various periods in sea water. Three series of standard briquettes were made up. The first series was mixed with fresh water and kept immersed in fresh water until broken.

* Engineer, Westinghouse, Church, Kerr and Company, New York, N. Y.

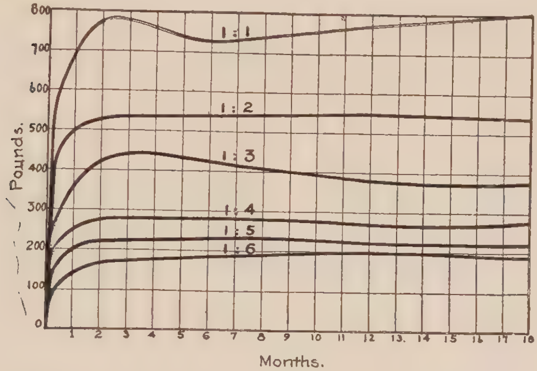

FIG. 1.—CEMENT SAND MORTARS MIXED WITH AND KEPT IN FRESH WATER.

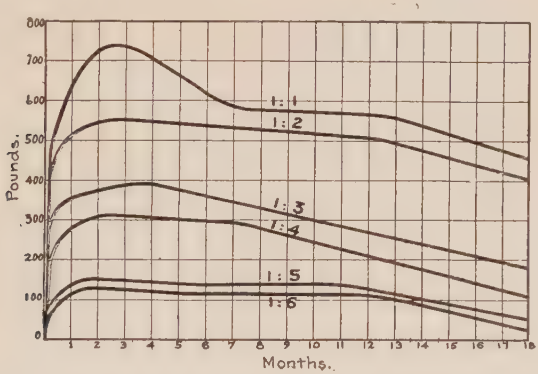

FIG. 2.—CEMENT SAND MORTARS MIXED WITH FRESH AND KEPT IN SEA WATER.

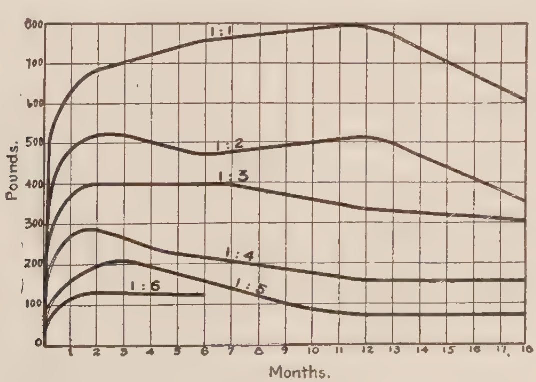

FIG. 3.—CEMENT SAND MORTARS MIXED WITH AND KEPT IN SEA WATER.

The second series was mixed with fresh water and kept immersed in sea water. The third series was mixed with sea water and immersed in sea water. The cement used was a brand of standard Portland cement. The sand used was Standard Ottawa, 20-30 mesh. The proportions of cement and sand varied from 1 : 1 to 1 : 6 by weight. Mixtures of the proportion of 1 : 7 were also made but as they all crumbled in the pans after a short time, they were discarded from the test. Briquettes were of standard size, with one square inch of cross section. They were kept in a damp closet for 24 hours after making then immersed in water in pans in the laboratory. Water from New York Harbor, taken at flood tide, was used in the pans containing the second and third series. This water was changed frequently.

Three briquettes of each proportion in each series were broken at the end of 7 days, 28 days, 2 months, 6 months, 12 months, and 18 months.

The results obtained are shown graphically by Figs.* 1, 2 and 3. They tell their own story.

It is unwise to draw conclusions from meagre information. These tests do not represent practical conditions. They are tension tests, while concrete is seldom subjected in practice to tensile stresses. The specimens were only one inch square at the breaking point and concrete is seldom, if ever, used in that size in sea water. The small area of cross section made it necessary for the action of the sea water to penetrate only ½ in. into each side of the test piece to affect the entire cross section. Whereas, on a pier of large size in sea water, the concrete would be damaged but a small percentage if ½ in. were entirely removed from its surface, yet successive removals of ½ in. at a time would ultimately be very injurious.

These results are presented, not with the claim that they support any theory or that they prove any point in the question of how to make concrete withstand the ravages of sea water, but as a record of tests made and results obtained which furnish evidence that the effect of sea water upon cement-sand mortar is to reduce its tensile strength.

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* Acknowledgment is made to the *Engineering News* for the cuts used in this paper. —ED.

DISCUSSION.

Mr. William M. Kinney.—I would like to ask Mr. Chapman as to the number of briquettes made for each test, and as to whether the results checked closely? **Mr. Kinney.**

Mr. Cloyd M. Chapman.—Three briquettes were broken for each series at each date, eighteen briquettes in all for each mix, in each series, broken on six dates. **Mr. Chapman.**

In probably nine cases out of ten the variation was not more than ten per cent. each side of the mean. But there were some erratic cases, and in those cases I eliminated the irregular results. For instance, if two out of three happened to break at about 250 lbs. and the third at about 125 lbs., or half as much, then the 125 lb. tests would be ignored and 250 lbs. taken as the true result.

Mr. Robert A. Cummings.—Did you make a chemical analysis or determine the amount of alumina? **Mr. Cummings**

Mr. Chapman.—The average analysis of the brand of cement used was known, but not that of the particular sample. **Mr. Chapman.**

The tests were made in our cement testing laboratory in New York City. They were laboratory tests with sea water from the incoming tide taken at the lower end of Manhattan, from New York harbor, and kept in pans in the laboratory. No analysis of the water was made except a determination of the grains of chlorides, assumed as NaCl and determined by tritrating with $AgNO_3$, using potassium chromate as an indicator.

The President.—Some tests made in New York harbor several years ago seemed to indicate that briquettes of Portland cement were very considerably reduced in strength and in some cases went to pieces while briquettes of natural cement were not so affected. It subsequently developed that these tests were made near the outfall of a main sewer and that the loss of strength was probably due to the action of sewage and not to the action of sea water. Tests are now being made by the government in connection with the construction of Dry Dock No. 4, Brooklyn Navy Yard, for the purpose of ascertaining the effect **The President.**

The President. of sea water on concrete. This is part of the government investigations of the effect of sea water on various structural materials. These tests were inaugurated during the Jamestown Exposition, the test pieces being exposed at the end of one of the exposition piers. The analysis of the water at that point, however, showed a very large percentage of fresh water which was quite variable, being particularly large during the spring freshets in the James River. The percentage of salt water at this point rarely ever exceeded 50 per cent., which was the case during heavy storms at sea, and was generally about 40 per cent. The point at which the test pieces were immersed was not more than one mile and one-half from the ocean.

In studying the available points for the establishment of the laboratory along the Atlantic Coast, the Boston and Portsmouth harbors and Atlantic City, were the only ones that seemed to be available for the purpose. But as the former two did not possess the requisite facilities, Atlantic City was finally agreed upon, the location at Norfolk, Va., being abandoned.

The location on Young's Old Ocean Pier at Atlantic City is such that a suitable depth of uncontaminated sea water is available without an objectionable littoral drift.

After visiting the various laboratories in Europe for the investigation of the effect of sea water on cement mortars and concretes, and from the results of similar experiments made in this country, I am of the opinion that in general the composition of the cement does not have as important a bearing on the ultimate ability of concrete to withstand sea water action as the character of the workmanship and the age of the concrete at the time it is exposed. However, I believe that our final opinion in the matter should be withheld until more conclusive data is available upon which to base conclusions. There is no question that where the concrete is properly proportioned, mixed and placed so as to secure the requisite density and it has attained a sufficient degree of hardness, that it can successfully resist sea water action. I have examined many structures in Europe and in this country and the reported damage to concrete structures from sea water have been the result, almost invariably, of bad workmanship and the action of frost. There are a few in-

stances where such action is possibly traceable to sea water. But in general it may be stated that where the concrete is properly mixed, placed and allowed sufficient time for hardening, it can be used in sea water successfully. This is proven through the existence of numerous structures of concrete in all parts of the world which are unaffected by sea water. **The President.**

MR. E. S. LARNED.—I would like to ask Mr. Chapman if in exposing the briquettes to sea water the latter was renewed from time to time. **Mr. Larned.**

How soon after taking out of the water were the briquettes placed in the testing machine?

MR. CHAPMAN.—The sea water was renewed frequently, once a week or so, and soon after immersing in sea water an insoluble deposit was formed, a delicate film or skin which was not intimately attached to the briquettes but was against them and was transparent in the water. This crusting began to take place within a short time after placing the briquettes in the trays. **Mr. Chapman.**

The reason I chose for exposing the test pieces in the laboratory instead of in the harbor, was on account of the sewage contamination and the fact that I would not get pure sea water. All the water was taken from the harbor after the tide had been running in for two or three hours, so that while I did not obtain the same water as five miles out to sea, yet it was more nearly like sea water than I would have obtained by taking it promiscuously or immersing the briquettes in the harbor.

The briquettes were tested immediately on leaving the water.

MR. LARNED.—In this paper I have observed some interesting criticisms, from which it appears that the time of breaking briquettes or examining the sample is quite important. **Mr. Larned.**

About six months ago, I was shown a concrete brick 4 ins. square in cross section and about 8 ins. long, in the center of which was embedded a ⅝-in. cold twisted square bar, flush with the concrete at one end, and projecting several inches at the other end. This sample was one of a series prepared to show the influence of sea water contaminated with sewage upon the concrete and exposed to steel, these samples being immersed near the effluent of one of Boston's sewers.

The sample above was the sixth of a series, and had been

Mr. Larned. exposed for six years, one sample being removed yearly to observe the results. The sample when observed was wet, having just been brought in from the exposure, and, with the aid of a cold chisel and hammer, I split this brick as near the middle as possible, leaving the steel rod embedded but exposed on one side. The outside of the concrete was at first a little soft for a small fraction of an inch below the surface, but the brick was split open with considerable difficulty, the steel rod for its entire length of embedment was bright, and showed no indications of rust, the end of the bar not protected in the concrete had diminished in diameter about 30 per cent. After the sample had been left in the office for some time, I observed it again and found the concrete hard throughout and comparable with any sample of concrete that had not been exposed to this combined action of sea water and sewage. This condition I note as an improvement in the hardness of concrete over its condition at the time of its first removal from the exposure, and it occurs to me that in the tensile tests noted in this paper that the time of breaking the briquettes would have an important influence upon the results.

Mr. Kinney. MR. WILLIAM M. KINNEY.—What kind of storage tanks did you use, Mr. Chapman?

Mr. Chapman. MR. CHAPMAN.—They were of galvanized iron.

Mr. Kinney. MR. KINNEY.—The use of galvanized iron storage tanks will undoubtedly greatly influence the results obtained, and in all probability the action of sea water on the galvanizing is responsible for some of that peculiar formation noticed on the briquettes. There is even some question as to the advisability of using galvanized iron tanks for fresh water storage of briquettes.

The President. THE PRESIDENT.—The Chair would also remark that he believes these tanks may have an unfavorable influence on the tests.

Mr. Chapman. MR. CHAPMAN.—What kind of tanks would you suggest, wooden tanks?

The President. THE PRESIDENT.—No, the Chair thinks the most preferable tank is of soapstone, but as these are expensive, cement tanks afford a satisfactory substitute since they can be constructed with very little expense, and will serve the purpose certainly much better than galvanized iron tanks. You can, of course, use enameled iron pans if the others are not available, and they are very much

better than galvanized iron pans. The assumption that a galvanized iron tank has no influence on the results is open to criticism, and as many variables as possible should be eliminated. **The President.**

A briquette is not a good form of test piece as the exposed surface of the briquette is so very great in proportion to the mass that the results are not comparable with those of the actual structures in sea water.

LAYING CONCRETE UNDER WATER—DETROIT RIVER TUNNEL.

By Olaf Hoff.*

In reviewing the great number of subaqueous structures as designed and constructed by engineers in the past, one cannot fail to note the hesitancy and diffidence with which they have approached the problem of depositing concrete under water, and how they apparently have resorted to this expedient, by way of compromise, where none other seemed available, except at an unjustifiable expense. The reasons are obvious; the chief difficulty among the many presenting themselves being to convey the mass of semi-fluid concrete mixture through the water to its place of deposit in such a manner as to preserve the mixture intact and prevent segregation of its integral parts, which would leave only an inert mass of aggregate. As a consequence the application of this method has been very limited, and the experience gained equally so. Various expedients and devices have been adopted for solving the problem, the principal ones being the use of bags, drop bottom buckets and tremies, all subject to objections peculiar to each. Laying concrete under water by means of bags involves the use of divers in placing the bags, and is accordingly cumbersome, slow, and expensive; the results are not wholly satisfactory and the method should be classed as obsolete. Neither is the use of drop bottom buckets all that could be desired; even with the greatest care it is not possible to prevent the mass from dropping a short distance through the water, which, thus set in motion, has a tendency to remove the cement from the aggregate and produce in spots a lean concrete, where a uniform and homogeneous structure is the ideal sought for. Irregular cleavage lines in the concrete are likely to occur, which objection is also applicable to the use of bags.

The depositing of concrete in water by means of tremies has heretofore presented difficulties, which have not always produced

*Consulting Engineer, New York, N. Y.

satisfactory results. A tremie is nothing more or less than a long tube reaching from the place where the concrete is to be deposited to the surface of the water above, its upper end being provided with a hopper for receiving the mixture. As fast as the concrete escapes at the lower end of the tube it is replenished at the upper end, thus flowing in a continuous stream.

Theoretically this is the ideal way of laying concrete under water, but when reduced to practice the object has not proven so easy of accomplishment. The difficulty has principally been to control the flow of the concrete through the tube and prevent the water from the outside to rush into the tube from below, thus washing the concrete and separating the cement from the aggregate, losing the charge; the concrete would be liable to run out either too fast or too slow. Generally the concrete has been deposited in layers of various thicknesses, governed by the position of the mouth of the tremie with reference to that of the layer below. This also of necessity results in a certain amount of motion of the concrete through the water, with attending loss of cement.

These difficulties were successfully overcome in the construction of the Detroit River Tunnel, more than one hundred thousand cubic yards of concrete having been deposited in water by means of tremies; the operation extending over a period of part of three seasons, 1907, 1908 and 1909.

In order to describe the methods used and convey a correct understanding of same, it will first be necessary to give a short description of the tunnel itself and more particularly the subaqueous part of same.

GENERAL DESCRIPTION OF TUNNEL.

The tunnel has a double track, built for the use of the New York Central System of railroad lines, passing under the Detroit River and connecting the City of Detroit, Mich., with the town of Windsor, Canada. It is built as two separate tubes with a center wall between each with an overhead clearance of 18 ft. above top of rail, and a length of 8,360 ft. from portal to portal. It consists of three sections, the westerly approach tunnel on the American side 2,135 ft. long, the section under the Detroit River

proper, or subaqueous section, 2,625 ft. long, and the easterly approach tunnel on the Canadian side 3,600 ft. long.

The westerly approach tunnel and adjoining end of the subaqueous section is on a two per cent. gradient and the easterly approach tunnel on a one and a half per cent. gradient. The subaqueous section has a level grade of some 1,000 ft., merging into the approaching gradients through long vertical curves at either end. It also has a short horizontal curve of two degrees curvature at the westerly end. The portals are approached through long open cuts at both ends of the tunnel.

The approach tunnels on both sides of the river were driven through a formation of plastic blue clay by means of shields. The same clay formation extends across the river and overlies bed rock which is found at a depth of some 10 to 30 ft. below the tunnel structure.

The subaqueous section was built on a unique and novel plan never heretofore used, which proved highly successful both as to cost, speed of construction and safety. It consisted in excavating a trench in the bottom of the river, of the required width and depth, into which steel tubes were sunk; these were thereupon encased in concrete laid under water, pumped out and then lined with concrete on the inside. The whole operation proved to be very simple and easy of execution.

The top of the tunnel structure generally follows the bottom of the river; at the middle it even projects a few feet above the bottom; at the deepest part it is 41 ft. 9 ins. below the surface. The bottom of the structure at this point is about 74 ft. below the surface of the river.

METHOD OF CONSTRUCTION.

The excavation of the trench was done with an ordinary clam-shell dredge, well in advance of the sinking of the tubes. The tubes were circular in form with a diameter of 23 ft. 4 ins. and were arranged and sunk in pairs, one tube for each track; they were built of 3/8 in. steel plates, see Fig.* 1. They were spaced 3 ft. apart between the shells and reinforced on

* Acknowledgment is made to the *Engineering News* for the illustrations used in this paper.—ED.

the outside by a series of transverse steel partitions or diaphrams, 12 ft. apart. These diaphrams extended all around the tubes and were approximately of rectangular shape with an extreme depth of 30 ft. 4 ins. and extreme width of 55 ft. 8 ins.; thus extending

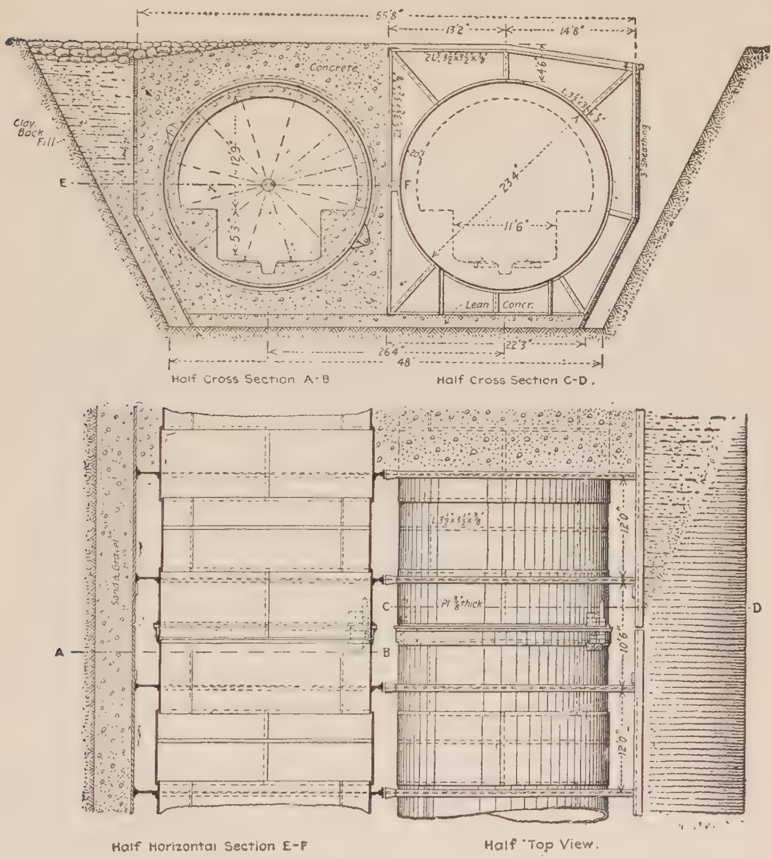

FIG. 1.—SECTION THROUGH SUBAQUEOUS PORTION OF THE DETROIT RIVER TUNNEL.

beyond the steel shell 3 ft. at the bottom, 3 ft. on the sides and 4 ft. on the top of the tubes. They were strengthened by means of double angle irons riveted along the edges; wooden sheathing running lengthwise of the tube was bolted along the vertical edges of the diaphrams. The tubes were built in lengths of 262

ft. 6 ins. and were provided with temporary wooden bulkheads at the ends so that they would float when launched.

For the purpose of sinking the tubes they were equipped with four buoyancy cylinders attached on top, which enabled the tubes when filled with water to be kept in suspension at any point, lowered to the final resting place by means of floating derricks and connected up with the tubes already sunk.

Before sinking a platform was built in the bottom of the trench at the proper level to temporarily support the ends of the tubes. When in their final position the tubes would underneath be from 5 to 7 ft. from the bottom of the trench, depending upon how near the correct level this was excavated. The diaphrams crosswise of the tubes and the wooden sheathing on the sides, parallel with the tubes, would then present in exterior view a series of pockets open at the top and bottom, but with enclosed sides and ends. Into these pockets concrete was poured by means of three tremies, one placed in the middle between the two tubes and one on the outside of each tube, between the steel shell and the wooden sheathing.

The mode of procedure in placing the concrete was, generally, first to concrete in the bottom to the under side of the diaphrams, thus sealing the pockets and affording support for the tubes. The buoyancy cylinders holding the tubes in suspension could then be removed, and each pocket filled with concrete in one continuous operation, forming a monolithic mass of a thickness of 3 ft. on the sides of and between the tubes, 4 ft. to 4 ft. 6 ins. on top of the tubes, and a thickness of 5 to 7 ft. underneath the tubes, varying with the irregularity of the bottom.

Generally every other tube length was provided with an extra strong bulkhead at the extreme end, capable of resisting the full hydrostatic pressure when the tubes were pumped out, in order to give access to the interior and permit the placing of the concrete lining.

The equipment used for the purpose of placing the subaqueous concrete consisted of a so-called tremie scow, especially designed and built for the purpose. The details of the tremie scow are shown in Fig. 2 on Plate II; Fig. 3 shows the tremie scow in the middle of the river, a near view being shown in Fig.

4. This scow was 35 ft. in width, 155 ft. in length and 9 ft. 9 ins. in depth with a free board of about 4 ft. It was equipped with 4 spuds, one in each corner, of 20 ins. square 90 ft. long Oregon fir timbers, and necessary spud hoists. The object of these spuds was to hold the scow steady during concreting, and prevent any rocking motions caused by waves, or the wash from passing steamers. The scow was further held in position against the

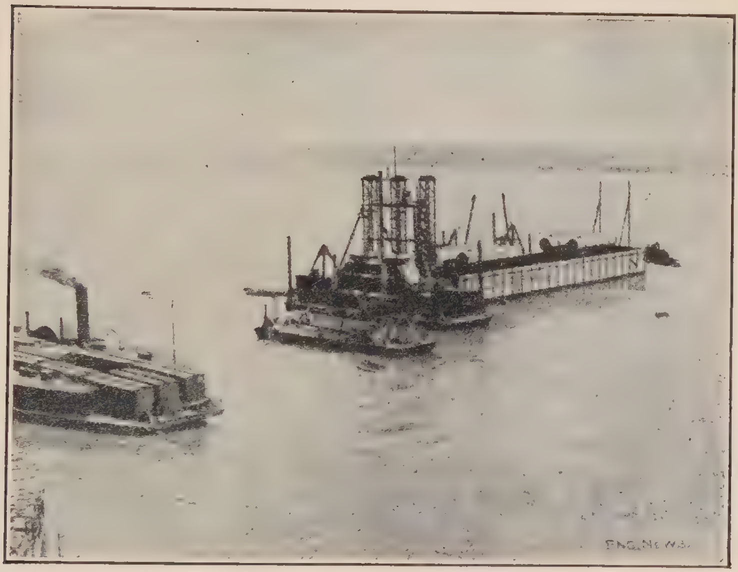

FIG. 3.—VIEW OF TREMIE SCOW IN MIDDLE OF RIVER.

current by anchors and was equipped with deck hoists for handling. On one side of the scow were built three towers 82 ft. high above the deck, one for each tremie; the front of these towers served the purpose of leaders (similar to those of a pile driver) for the tremie pipes, which could be hoisted clear out of the water or lowered down to the bottom of the trench, as required. There were three concrete mixers, one for the middle tremie with a capacity of about 30 cu. ft. to the batch, and one for each of the side tremies with a capacity of about 20 cu. ft. to the batch. The equipment further consisted of an air compressor, a dynamo and an electric conveyor for conveying cement

to the charging floor from scows alongside the tremie scow, three hoisting engines for the tremies, two large derricks with hoisting engines for unloading gravel, and a 150 H. P. boiler.

Gravel was used for mixing the concrete in preference to broken stone; it was of size grading downwards from that of small walnuts. Mixed with approximately the proper amount of sand, it was found and pumped out of the river near Port Huron, Mich., some 60 miles away from the tunnel site and transported in boats or barges down the Detroit River to the tunnel. The tremie scow was designed particularly for the purpose of handling and mixing this gravel as cheaply as possible. The gravel was unloaded directly from the boats to the tremie scow and used up about as fast as unloaded. To this end the tremie scow was equipped with two heavy derricks located about at the quarter points of the scow on the opposite side to that of the tremie towers. These derricks were operated by large hoisting engines located on the deck of the scow, the gravel being unloaded by means of clam-shell buckets and discharged into two hoppers located 32 ft. above the deck of the scow, immediately behind the towers. From these hoppers the gravel would fall over inclined screens into receiving bins, being thus screened by gravity, the sand running off into one bin and the gravel into another. There was one sand bin and one gravel bin for each tremie. The bins for the center tremie were of about twice the capacity of the others, because this tremie had to deposit approximately twice as much concrete. The screens below the unloading hoppers were four in number, two for each hopper, inclined in opposite directions so that the gravel would feed one-half to the bin of the side tremie, and one-half to that of the center tremie. The sand and gravel bins were placed a few feet above the charging floor which was located 11 ft. above the deck of the scow, and was on a level with the top of the charging hopper of the concrete mixers. Through gates in the bottom of the bins the proper amount of gravel and sand could be drawn into the charging hoppers. This floor was large enough to hold a sufficient quantity of cement for one pocket. The water tank was also located on this floor, from which water was piped to the mixers.

The concrete mixers were placed directly on the deck and

PLATE II.
PROC. NAT. ASSN. CEMENT USERS.
VOL. VI, 1910.
HOFF ON LAYING CONCRETE UNDFR WATER.

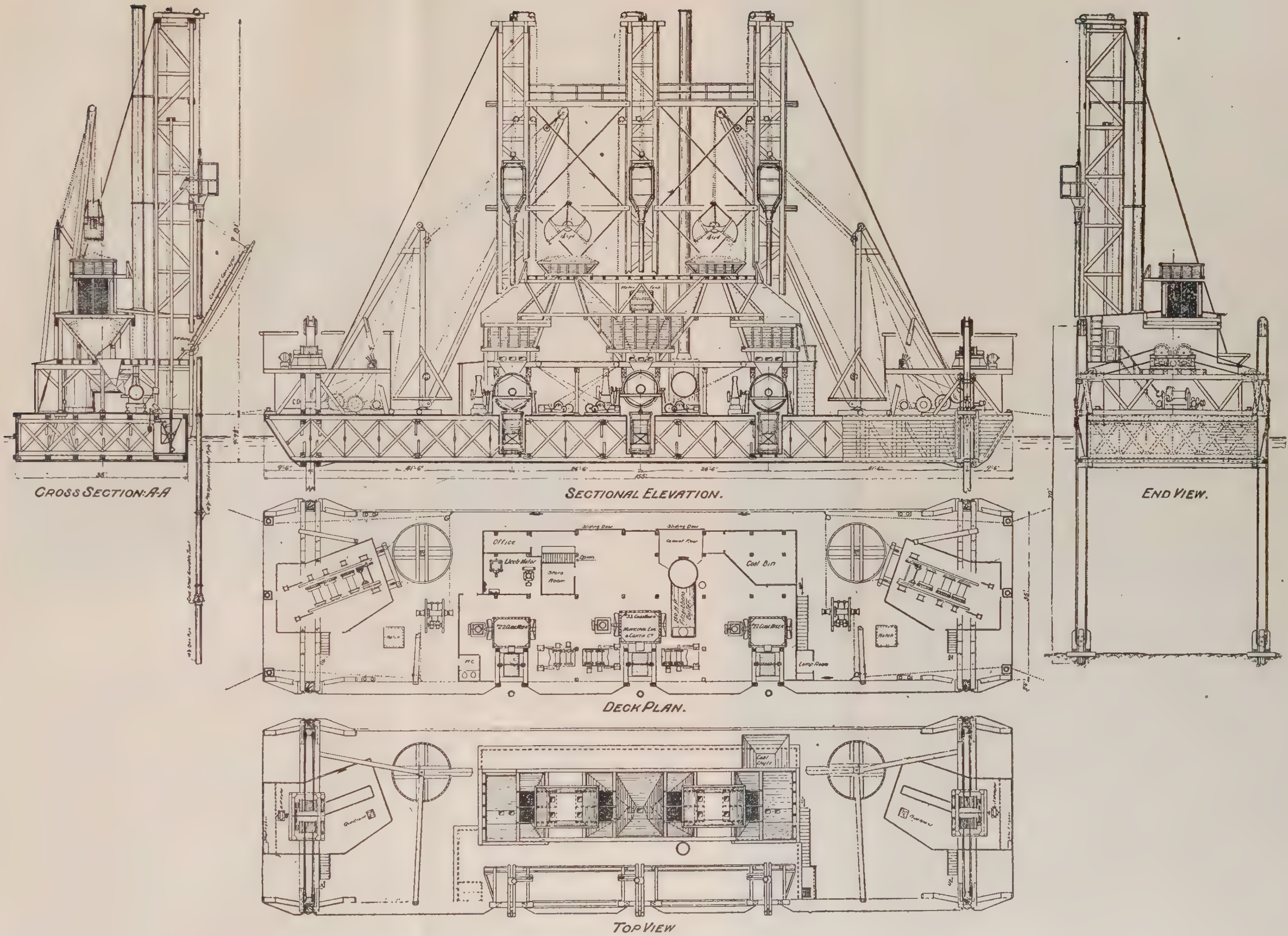

FIG. 3. DETAILS OF TREMIE SCOW.

when tilted would discharge into self-dumping buckets, placed in the hull of the scow directly in front of the mixers; these buckets could be hoisted up to any point where the receiving hoppers of the tremies might happen to be located and discharge their contents into same.

The total amount of concrete in one pocket was about 342

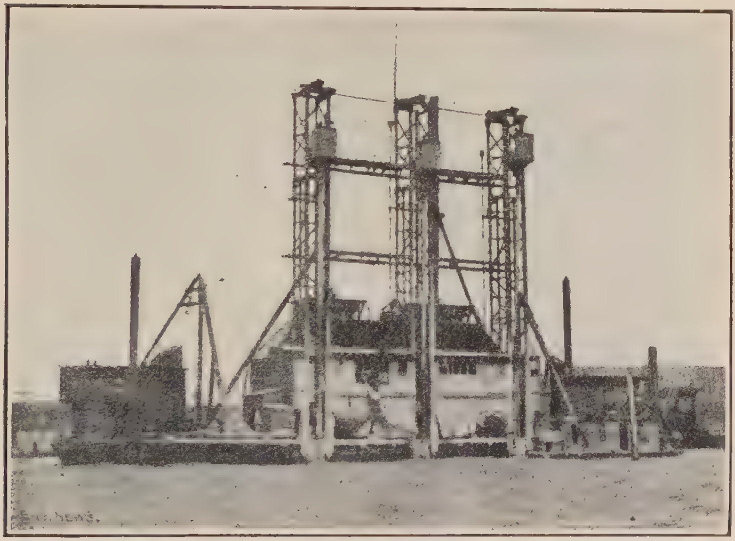

FIG. 4.—NEAR VIEW OF TREMIE SCOW, CONCRETE DEPOSITING ON SUBAQUEOUS PART OF THE DETROIT RIVER TUNNEL.

cu. yds., of which approximately one-half had to be deposited through the center tremie and one-fourth through each of the side tremies.

Each tremie consisted of a 12 in. diameter spiral riveted steel pipe of No. 10 metal, 80 ft. long made in 20 ft. lengths provided with external flanges for bolting up. The upper end of the tremie pipe was suspended from a frame, to which was attached a hopper for charging the tremie, the hoppers with frames running between guides attached to the front of the beforementioned towers. The tremie pipes, hoppers and all could be raised and lowered by means of steel hoisting ropes leading over sheaves at the top of the scow. The buckets in the hold of the

scow upon receiving a charge from the concrete mixers were hoisted up inside the towers until they reached the tremie hoppers, which would engage them and trip them forward, discharging their contents into the hoppers; then they would reverse and go down to their place in the hold of the scow. These buckets ran between guides located inside the towers immediately in the rear of the guides of the tremie hoppers. The concrete in passing from a mixer into the bucket would discharge over an apron, which the bucket would trip forward every time it descended and trip back out of the way when hoisted up. The tremie hoppers were provided with a small platform on the outside and a railing around same where a man could stand and watch the concrete in the tremie, whether it was running out too fast or too slow, and give signals accordingly to the engineer who ran the corresponding engine.

The working force for operating the tremie scow, when the process of concreting was going on, was thirty-two men, on an average.

The operation was as follows: The tremie scow was anchored across the tunnel tubes in the trench, so that the tremies when lowered into place would come in the middle of a pocket, as already stated, one tremie between the tubes and one on the outside of each tube between the steel shell and the sheathing. The spuds were then lowered to the bottom and forced down sufficiently to take up a considerable load from the scow and prevent any rocking motions. The three tremie pipes were lowered into position until their lower ends rested on the bottom of the trench; the water inside of the tremie tubes would of course be at the same level with the water outside. Meanwhile the boat loaded with gravel would be placed alongside the tremie scow on the opposite side. The gravel with its mixture of sand would then be unloaded by means of the clam shells and derricks, and dropped into the hoppers previously described, falling over the inclined screens, the sand and gravel shooting off into their respective bins, from which they would in turn be drawn, as required, into the upper hoppers of the concrete mixers, cement added, and the charge shot into the mixers, where the necessary water was added in the usual way.

A wadding of cement sacks was at first placed in each tremie on top of the water to prevent the concrete from dropping through while filling the pipe. A batch of concrete was discharged from the mixer into the bucket in the hold of the scow and hoisted up until a projecting arm on the receiving hopper of the tremie would cause the bucket to tilt forward and discharge the contents into the tremie hopper and on top of the wadding, the bucket immediately returning to its original place to receive a new charge, already in the process of mixing. When this hopper was about half filled, the tremie and hopper would be raised a trifle, permitting the water in the tremie to escape at the bottom as the weight of the concrete pushed the wadding downwards through the pipe. Meanwhile fresh batches of concrete were being dumped into the tremie hoppers. In this manner the tremie was filled with concrete until the wadding reached the bottom and the concrete commenced to run out of the pipes. As fast as the concrete ran out at the lower end of the tremie pipe, fresh concrete would be added to the upper end of same, this process going on until the whole pocket was filled.

The wadding of cement bags was used only at the beginning of the work. It was soon found that one or two dry batches of concrete would serve the same purpose, and this was used practically throughout the work in charging the tremie at the beginning of an operation.

The concrete, except as noted in charging the tremies, was mixed very wet, much more so than would be permissible in concrete deposited in the air. No difficulty, however, was experienced on this account. The gravel showed no tendency to segregate from the mixture, probably because the mass was always in a slow and uniform motion, and when it reached its place of deposit the mass would be under a heavy hydrostatic pressure, that may have had the effect in connection with the loss of weight on account of buoyancy, of making segregation more difficult.

It should be particularly noted, that the mouth of the tremie was always buried in the concrete from 2 to 5 ft., forming an effective seal which at all times prevented the outside water from forcing itself into the tremie. It was the duty of the inspector on the platform of the tremie hopper to always be on the

lookout, that the tremie was full of concrete. If the concrete showed a tendency to run out too fast he would signal the hoisting engineer to lower the tremie and thus choke off the flow; if the concrete did not flow fast enough he would order the tremie raised until the concrete would flow more rapidly.

It is a fact, that after a week or so, when the men on the concrete scow had become thoroughly familiar with their duties not a single charge was lost in depositing more than one hundred thousand cubic yards of concrete. The concrete when deposited would take an exceedingly flat slope, in fact practically seek its own level. Occasionally a small mound would be built up around the mouth of the tremie, but the least agitation of same would cause this mound to spread out to a practically level surface. As soon as a pocket was finished the concrete scow was shifted to the next one. No pocket was ever started unless the necessary materials of sand, gravel and cement were on hand to complete it.

In depositing the concrete divers were employed for inspecting the progress of the work, and report when a pocket was completed. The time required for filling one pocket usually ran from four to seven hours. The largest amount of concrete placed by the tremie scow per day was three pockets or 1,025 cu. yds., working sixteen hours. This includes the time required for replacing the gravel boats alongside the tremie scow. These boats generally held enough gravel for one pocket. The amount of concrete that could be placed depended mostly upon the supply of gravel. Usually three pockets were concreted in two days, that is one pocket one day and two pockets the next.

As previously stated, the bottom of the trench was first filled with concrete, to the under side of the diaphrams; this generally required from four to five days, sometimes a little longer, for each tube length.

The length of time of mixing a batch was usually from two to three minutes. The time for the concrete to reach its place of deposit from the mixer would of course vary greatly, but the average time was probably about eight minutes, with a minimum of five minutes and a maximum of fifteen. The velocity of the flow of concrete in the tremies would average from 14 to 15 ft. per minute; the extreme probably running from 7 ft. to 25 ft.

When the work first commenced the side tremies were made of 10 in. pipe as against 12 in. for the center tremie. This was done because the amount of concrete passing through each of the side tremies was approximately only half of that of the center tremie. After the first section had been completed all three tremies were made 12 ins. in diameter for the sake of convenience, as by that time it was found that the flow of the concrete could be absolutely regulated to suit the requirements. The wear and tear on the tremie pipes proved very insignificant, the full set of tremies having been renewed only once.

The concrete was mixed in the following proportions: In the bottom of the trench below the diaphrams it consisted of one part of cement to four parts of sand and eight parts of gravel. The concrete in the pockets consisted of one part of cement to three parts of sand and six parts of gravel. Gravel of small walnut size was used in preference to crushed stone, as it was thought it would cause the concrete to flow easier in the tremies. Besides gravel makes a denser concrete than crushed stone.

In some of the pockets at the joints between two sections the concrete was made in the proportions of one part of cement to two of sand and four of gravel. The reason for making the concrete in these pockets richer was simply a matter of precaution, taken to insure a tight joint, the steel work not fitting together as closely as intended. When the tubes were pumped out no water came through these joints, showing that the 1:2:4 concrete was practically impervious to water, although subject to a hydrostatic pressure of about 25 lbs. per sq. in.

For the purpose of determining the quality of the concrete, 6 in. cores were taken out by means of a Davis Calyx drill for the full height of the center wall between the steel tubes. These cores show a remarkable degree of uniformity of the concrete and of high quality both as to density and strength; in fact a better grade of concrete was obtained than would be possible in the open air. It should be noted in this connection that this concrete was compressed and set up under a hydrostatic pressure of from 16 to 30 lbs. per sq. in. at the top and the bottom of a pocket respectively. The crushing strength of this concrete when one year old ran from about 2,800 lbs. per sq. in. minimum to

4,000 lbs. per sq. in. maximum, for a mixture 1:3:6, according to tests made upon cores taken from the center wall.

A word should be said with respect to the time of setting or hardening of the concrete; this is, to be sure, a debatable subject. However, the consensus of opinion among the engineers connected with the work, including the writer, based upon such tests as could be made by divers, seemed to be that the initial set was acquired in about 10 hours after the concrete was deposited, and the final set in 20 hours; after 40 hours the concrete was very hard, so that it would ring when struck with an iron bar.

Regarding the matter of laitance, hardly any was observed that would affect the quality of the work; this might be expected considering the manner in which this concrete was deposited, whereby the great mass of it would never come in contact with the water at all.

ELEMENTS ESSENTIAL TO SUCCESS.

It may not be amiss to point out the three essential elements that contributed to the successful results in depositing the subaqueous concrete of the Detroit River Tunnel; they are as follows:

First, dividing the exterior of the tunnel tubes, by means of the longitudinal sheathing and the diaphrams, into compartments or pockets. This produced still water, which is absolutely essential for laying concrete under water, and permitted the filling of one pocket at a time with one monolithic mass of concrete. This arrangement further limited the lateral flow of the concrete, as it emerged from the tremie, to the confine of the pocket and reduced the washing out of cement by the water to an absolute minimum; in fact, the loss of cement appeared to be negligible.

Second, the use of an equipment complete in every detail and equal to any demand made upon it, more especially an active or quick acting rig for handling the tremie pipes promptly, as occasion required.

Third, mixing the concrete so wet that it would readily flow in the tremies, and the flow controlled by keeping the mouth of the tremie at all times buried in the concrete at a sufficient depth, thereby at the same time keeping it sealed and preventing the water from rushing in from the outside.

OTHER APPLICATIONS OF TREMIE METHOD.

The demonstration of these highly successful results on such a large scale suggests possibilities of the application of this method to various kinds of engineering works, other than subaqueous tunnels. Numerous instances will undoubtedly from time to time present themselves where this method could be used to advantage, not only as an expedient of construction, but at a great saving in cost over prevailing methods, especially where large and expensive coffer-dams would be avoided. The subaqueous concrete of the Detroit River Tunnel was deposited at a considerably less expense, including the cost of the plant, than similar work could have been done for on land.

It may perhaps be permissible, in conclusion, to venture a few suggestions of such applications. Structures, now frequently built of cyclopean concrete blocks, such as dock and quay walls, breakwaters, etc., could in many instances be built *in situ* by using steel forms constructed on the compartment or pocket principle, which would result in obtaining monolithic and massive blocks, or sections of structure of far greater magnitude, than otherwise possible. The steel forms could be built extremely light and left in place, or heavier and detachable to permit their being used over again, as economy and expediency might dictate. If piles were required for providing a proper foundation they could be driven after the excavation was done to the required level, the forms set over them and then imbedding them in the concrete. Similarly dry docks, lighthouse foundations and bridge piers could be constructed, always of course depending upon local conditions and circumstances as to the applicability of the method.

DISCUSSION.

Mr. Wason.

MR. LEONARD C. WASON.—I would like to ask as to the length of the compartments which were filled at one time and how far the tube was imbedded below the surface of the concrete when that flowed out.

Mr. Hoff.

MR. OLAF HOFF.—Diaphrams which were of ¼-in. steel plate, built so that they extended around the tubes, together with the sheathing that was bolted on the sides of the diaphrams, formed the pockets. These diaphrams were 12 ft. apart, so that it made the length of the pocket 12 ft., or you may call it the width, possibly, because the other dimension is the larger. Now the width of the tunnel was 55 ft. 8 ins., taking in the two tunnel tubes each 23 ft. 4 ins. in diameter, with 3 ft. between the tubes and 3 ft. on each side of the tubes, making the exterior of the concrete 55 ft. 8 ins. The depth of the pockets from the top of the diaphrams to the bottom of the trench, would be something like 33 or 34 ft., depending upon the irregularity of the bottom. Of course the dredges were not able to dig out the trench any closer than say within 2 ft. from the exact elevation, that is, from 1 to 5 ft. of the level of the underside of the diaphrams. This space was always filled in with the cheaper grade of concrete, the 1:4:8. Now the depth of the concrete below the steel shell would then run from 5 to 8 ft., the average being 7 ft.

The concrete was placed so wet that the pressure of the concrete inside would cause it to ooze out gradually, being partly countered by the pressure of the water outside. The concrete surface, once formed, would gradually rise so that the freshly deposited concrete would hardly ever come in direct contact with the water. In order to cause the tremie to be sealed so that the water could not come in from the outside and at the same time permit the concrete to flow, the mouth of the tremie was buried from 2 to 5 ft. in this soft mass of concrete.

MR. HARRY F. PORTER.—Did the concrete deposited under water expand or contract in volume, and would it make any difference if it was sea instead of fresh water? Also was the concrete plain or reinforced? **Mr. Porter.**

MR. HOFF.—I should not think the kind of water would make any difference. **Mr. Hoff.**

We never had any difficulty with expansion or contraction. The work turned out very successfully, and of course to actually say whether it did do the one or the other would be very difficult. I cannot think just now of any method of determining the expansion or contraction, though it probably could be done.

Plain concrete was used.

MR. JOSEPH A. BLACK.—I understand a pocket was filled each day. I would like to know if the apparatus was moved the next morning in order to complete the next block or were long blocks built? **Mr Black.**

MR. HOFF.—The apparatus remained permanently in place. The diaphrams served as reinforcement to the steel shell, so that they are permanent, forming a part of the permanent structure. **Mr. Hoff.**

MR. E. S. LARNED.—The steel tubes were not anchored in any way, were they? **Mr. Larned.**

MR. HOFF.—Yes, when the steel tubes were being sunk and lowered in place on the platform that I have mentioned, they were anchored temporarily against the current and when in position bolted to that platform, simply to hold them in place laterally for the time being and until part of the bottom could be concreted in. This done, the tubes remained there and could not be shifted. **Mr. Hoff.**

APPLICATION OF CONCRETE IN BARGE CANAL WORK.

By Russell S. Greenman.*

The present canal system of the State of New York connects Lake Erie at Buffalo, Lake Ontario at Oswego, and Lake Champlain with the Hudson River at Albany—a total length of canal of 431 miles. The people of the State decided at the election of 1903 to issue bonds not to exceed one hundred and one million dollars to enlarge the existing canal system so that the demands of the present day for cheap water transportation might be met. The old canal had been outgrown by the commercial prosperity and progress. The plan was to construct a canal that would take care of boats, or barges, of a thousand ton capacity. The term, "The 1,000 Ton Barge Canal" became the title of the new canal, but the name soon became shortened to "Barge Canal." This title admits of the later capacity of the barges for it was decided by the State Legislature in 1905 to increase the width of the canal locks and then boats having a capacity of 2,000 tons might be carried on the canal.

The laws of the State now demand that the canal shall be of minimum depth of 12 ft. throughout, a minimum width of bottom of 75 ft. through land sections and of 200 ft. through the rivers and lakes, a length of lock between hollow quoins of 328 ft. and a width of lock of 45 ft. To build this larger canal with as economical a plan as possible, with the many different engineering problems to be overcome, became the special object of those placed in charge of carrying out the will of the people. To construct the canal as proposed, it was found necessary to canalize rivers, cross lakes and marshes, take care of spring floods, provide storage water for the dry seasons, and overcome a maximum difference of 565 ft. elevation between terminals.

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* Resident Engineer in charge of Tests, Department of New York State Engineer and Surveyor, Albany, N. Y.

The structures needed for the purpose of overcoming these problems—being the major factor of the cost—were to be built of as cheap a masonry as was consistent with the effectiveness and serviceability of the structure. Cut-stone masonry, such as was used on previous canal improvements, would add to the cost greatly over concrete. After carefully considering the advisability of using concrete, it was decided that it would easily meet all the needs of the project and would certainly keep down

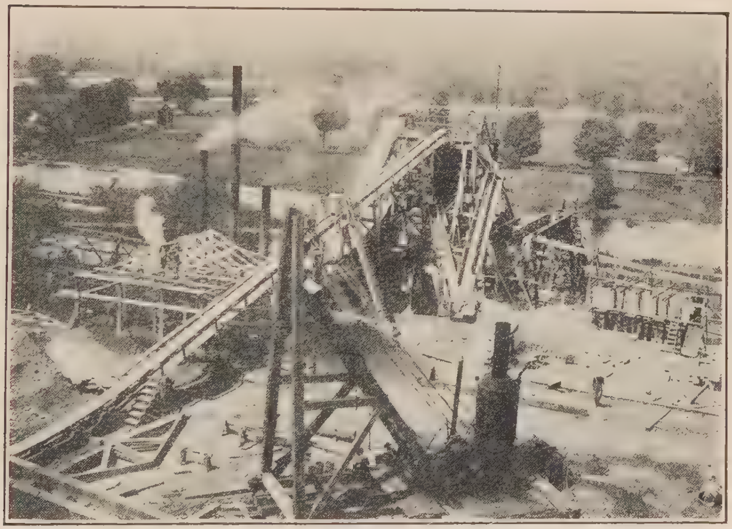

FIG. I.—SAND AND GRAVEL WASHING AND SCREENING PLANT.

the cost. This decision was reached only after a careful examination of concrete structures which had been built for some time and which were similar to those proposed for the Barge Canal. From the present viewpoint of the constructing engineer it seems strange that but seven years ago it was a wise move to hesitate to use concrete in such large structures and to such a large extent as called for by the Barge Canal project.

To provide for structures for different uses three grades of concrete are specified. First-class concrete calls for a mixture of proportion of one part cement, two parts sand and four parts

stone. The stone must be a hard trap-rock, granite or gneiss. This grade is only used in cases where an especially fine concrete is needed. Second-class concrete is a mixture of one part cement, two and one-half sand and five parts stone or gravel. By far the larger part of the concrete work is built of this grade, and among the structures now being built of it are the locks, dams, bridge piers and abutments, breakwaters and retaining walls. There are 53 locks as above, and are estimated to cost with their approach walk about $16,000,000. The third-class concrete is one part cement, three parts sand and six parts stone or gravel. This grade is not used much, except in core walls and similar less important work.

The work is all executed by contract and because of the various conditions existing in different sections there are many ways of carrying on the work of construction. The supervision of the construction is under the direction of Mr. Frank M. Williams, State Engineer and Surveyor of the State of New York, Harry W. DeGraff, Deputy State Engineer, and William B. Landreth, Special Deputy State Engineer, in special charge of the Barge Canal work. A large corps of assistants is necessary —demanding an organization of engineers such as is seldom required on any other work.

INSPECTION OF MATERIALS.

For the construction of the vast amount of masonry it was, of course, necessary to provide the best inspection of materials and workmanship. All materials proposed for use in the making of the concrete are carefully examined and tested, and experienced men are placed as inspectors on the structures in progress.

As in all other large projects careful attention is given to the cement proposed for use. The engineer in charge of tests made visits to many of the leading laboratories and selected the best ideas in use. The laboratory was enlarged and thoroughly equipped with the very best apparatus for the testing of cement. Carefully trained testers follow the standard methods and make all standard tests.* These consist of tests for setting, fineness,

* See Standard No. 1, National Association of Cement Users.—ED.

constancy of volume, tensile strength and specific gravity. Chemical examination is also made.

It was originally planned that the tests should be made on cement that was delivered in the storehouse on the work. The samples were taken from the stored cement and sent to the laboratory at Albany for the required tests. Tests were started as soon as the samples were received and the results were promptly given but, at best, 10 to 12 days elapsed from the time the samples

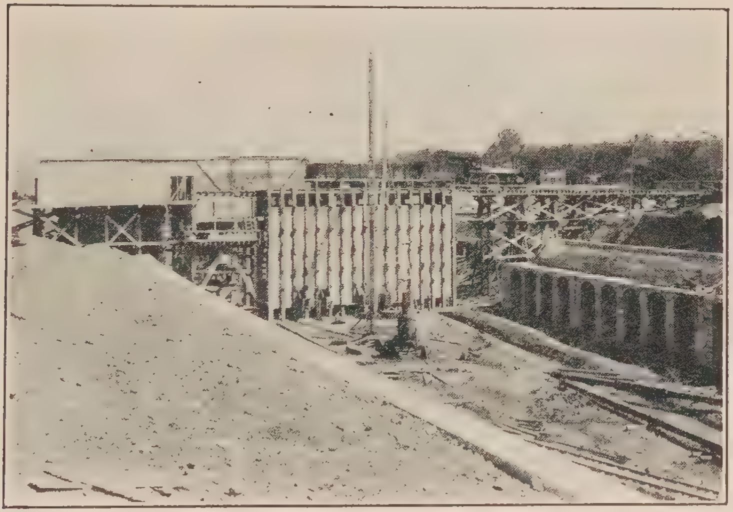

FIG. 2—CONCRETE MIXING PLANT. RECESSED RETAINING WALL UNDER CONSTRUCTION.

were taken, shipped by express to the laboratory, given a 7-day test and reported to the engineer in charge of the contract. A contractor using large quantities of cement therefore had to have a large cement storehouse in order to always have accepted cement ready for use. Gradually a system of mill inspection of cement was developed. When a contractor places with a cement company an order for cement that is large enough to warrant stationing an inspector at the mill, an inspector is directed to sample one or more bins of cement, depending on the size of the bins. These bins are sealed with a seal of the Depart-

ment of the State Engineer and Surveyor. The samples are forwarded by express to the testing laboratory at Albany and immediately tested. If the cement meets the requirements of the specifications it is accepted and held subject to the order of the contractor. Whenever this contractor wishes shipments made to the work, the inspector breaks the seal on the bin, inspects the loading of the car, or cars, seals each with the department seal, re-seals the bin and notifies the Resident Engineer in charge of the laboratory and the Resident Engineer in charge of the contract. When the cars arrive at the work, the seal must be intact and must be broken open only by the engineers on the contract. By this method only accepted cement is delivered on the work; and if he cares to do so, the contractor can use it immediately upon its arrival. The shipments from the mills have gradually increased until, on October 25, 1909, a high-water mark of 31 car loads, or 5,150 barrels of accepted cement was inspected for the Barge Canal. The daily average for the week was 2,911 barrels. The amount of cement shipped is used as an indication of the amount of structural work being done by the contractors.

In the selection of aggregates for his concrete the contractor is first guided by the classification of his concrete and then he naturally wishes to use that material which he can secure most cheaply and still keep within his contract. However, in order to insure good concrete, proper sand and stone as well as cement must be used. The State therefore demands that the sand or screenings, and the stone or gravel, shall be approved by the Department of the State Engineer and Surveyor. Samples of these are sent to the Testing Laboratory and carefully examined and tested. The sand is examined under the microscope as to the character of its grains; it is passed through a nest of sieves to secure the grading and sizes of the sand grains; and both in the natural condition and washed it is tested with cement for strength; and also tested for percentage of loam and voids.

If there is no good sand or gravel within economical hauling distance from the work, the contractor must necessarily import such material. In one notable instance, however, the contractors found that it would be more economical to wash and screen the gravel. They erected a plant at a cost of $90,000 and it is prob-

ably the largest temporary washing and screening plant ever erected (see Fig. 1). The capacity of this plant is 200 cu. yds. of gravel per hour.

In some cases where a desirable sand cannot be easily obtained, crushed stone screenings are used in place of the sand. It is required that these screenings shall be crushed from a hard

FIG. 3.—BELT CONVEYING SYSTEM. MIXING AND CONVEYING CONCRETE.

durable stone and that the particles shall be well graded. An excess of fine dust or powder must be screened out.

The crushed stone, proposed for use, must be from an approved kind and quality of rock—free from dirt and organic matter. In second-class and third-class concrete, gravel, which is composed of hard and durable stones, may be substituted for crushed stone. Either stone or gravel must be examined for the percentage of voids and the proportion of matrix may be varied so that there shall be an excess of 20 per cent. of matrix over the natural voids of the loose aggregate.

In the structures where the concrete is massive cyclopean concrete is permitted and in many cases the contractors are using

this kind of concrete. The specifications permit in massive concrete of the second or third-class, where the section is not less than 4 ft., the placing of boulders and fragments of rock containing more than one cu. ft. These must be made free from all dirt and must be placed on their largest bed. They must be kept at least 6 ins. apart and none shall be within 2 ft. from the surface. The contractors who have taken advantage of this permit to make cyclopean concrete have, as a rule, used only very large stone in massive structures as are some of the dams.

In connection with routine testing and inspection of materials frequent tests are made along special lines. Many of these have been made on the use of salt during freezing weather, amount of loam that is permissible, addition of colloidal clay in order to produce impervious mixtures, the substitution of crushed stone screenings or iron-ore tailings in place of sand, the use of various waterproofing compounds and the various methods of surface finishing. Just at present there is being conducted the second section of a very interesting series of tests on small arches—built as models of an arch of 285 ft. span which is proposed for carrying the Barge Canal over a gorge at Medina, N. Y. These tests are along lines of investigation practically new as far as the application of concrete to arch construction is concerned. Six arch models have already been tested and six more have been constructed and will be tested within a short time. In connection with these arch models an auxiliary series of tests on cubes and prisms have been made. Some results and data have already been secured that will be of very great value to the engineering world.

METHODS OF MIXING AND PLACING CONCRETE.

The large contracts under which the work on the Barge Canal is executed make large plants possible and even necessary. As has been suggested there have been tried many ways of doing this large work. There is the usual variation in the manner of mixing and placing concrete, and also in the large plants for the work.

The specifications demand that, in all work where more than 200 cu. yds. of concrete is to be placed, the mixing shall be done

by machines. Batch mixers only can be used and of these very many kinds are in use. Those most generally used are the cylindrical, or cubical drum and the gravity mixer. The latter has been used both in a stationary position and as a movable mixer—being carried by a derrick from the place of loading to the place of depositing the concrete.

The mixing plants are sometimes stationed directly in the newly excavated canal channel and the materials are hauled over

FIG. 4.—BELT CONVEYOR IN CENTER OF LOCK NO. 5.

trestles and emptied into hoppers over the mixers (Fig. 2). Most plants are, however, placed at some point conveniently located near to rail or water service, and the materials are transferred after being mixed. Some have the mixers on cars or movable platforms and empty the mixture directly from the machine into the forms.

In transferring the mixture from the mixer to the forms, when the two are much separated, various methods are used. The most popular method is the common bucket and car arrangement while others have preferred to transfer the buckets by cables. In one case, however, a belt conveyer system has been used.

Because of the amount of concrete handled by this system, special consideration can well be given to it. Within a radius of one mile from Lock No. 4, several massive concrete structures, aggregating a quarter of a million cubic yards of concrete, are planned to be constructed. Between two massive locks which, with the adjacent structures, would need about 100,000 cubic yards of concrete, the first part of this plant was built. A capacity of 500 cu. yds. per working day of 8 hours was planned. The

FIG. 5.—LOCK NO. 2 AT WATERFORD.

maximum output has been 450 cu. yds. or practically 1 cu. yd. per minute. To handle this quantity of material the following method was used (see Figs. 3 and 4): The sand and stone are dumped into separate hoppers over belt conveyors and carried by them to bins over the mixer. When the bins are filled the sand or stone automatically passes through a chute into storage bins. The cement storehouse has a capacity of 10,000 barrels of cement. Through the center of this passes a belt conveyor which carries the bags of cement up to the mixer. A great saving of labor in the handling of these raw materials is accom-

plished by this system as the only labor is in shoveling the sand or stone from the end of the car to the center and the placing of the bags of cement on the conveyor. The concrete mixture is then carried by belt to the locks on three series of belts moving at the rate of about 450 ft. per minute, each succeeding belt moving a little faster than the previous one so that there will be a better division of the material that comes from the mixer. At the locks there was a large tripper car with a boom

FIG. 6.—DAM AT VISCHER'S FERRY, SHOWING CYCLOPEAN MASONRY.

45 ft. long. The concrete is tripped from the main belt to the boom belt. The boom would swing over an angle of 200 degrees and reach either side of the lock. In carrying the concrete on the belt a mixture, somewhat drier than desired, had to be used. To produce the proper consistency, water was piped to the end of the boom and added to the mixture as needed. As it left the boom belt the concrete was collected into a narrow space by means of spouts. These were hung so as to swing freely and the concrete could be deposited at any point desired. The lock walls were, as a rule, built in 40 ft. sections with the forms providing for a depth of concrete of 6 ft.

The plan just described was altered somewhat on one of the locks by doing away with the trestle in the center of the lock and building a light steel skeleton right on the site of the side of the lock. On this the belt was run and as the concrete reached the top of the skeleton a new section was built on top of the old and the old became an integral part of the lock—a reinforcement, as it were. It is claimed for the belt conveyer that it has decided advantages over a bucket and car method as it keeps the particles together and prevents the separation often occurring with the other methods. The whole mixing and conveying plant, just described, is operated by electric power.

There are definite rules and requirements for the proper placing of concrete into the forms. Care must be taken that the concrete shall be in place before the cement shall have taken an initial set, that it shall be put in place in layers so that it will make a dense and impervious monolith, and that newly laid concrete shall be protected against freezing when placed during the cold months.

THE STRUCTURES.

It depends on the viewpoint as to which is the most interesting class of structures on the Barge Canal. By reason of their large number, large dimensions and fine design and construction, the locks appeal to almost every one. In the illustrations one has only to consider the size of a man to obtain by comparison some idea of the size of the lock, or to consider an old lock adjacent to the new. There are to be 53 lift locks. These locks have a minimum length of 328 ft. between hollow quoins, the width being 45 ft. The lift varies from 6 to 40½ ft. The latter lift is at Little Falls and at the time of completion will undoubtedly be the highest lift of any mitered-gate lock in operation. The locks are built of second-class concrete and are constructed in sections of approximately 40 ft. in length. Each section is carefully keyed into the adjacent sections.

The locks are to be filled by means of a culvert running through either side of the lock walls. The flow from the cul-

verts into the locks is through 14 port-pipes on either side. These pipes are of cast iron and are each 3 ft. in diameter. The lock gates, valves and all machinery are to be operated by electric power, generated at power stations to be erected at various points along the canal.

In constructing the locks all kinds of difficulties have been met. In some places piling is necessary to support the foundation; in other cases the locks are constructed in rock, notably so

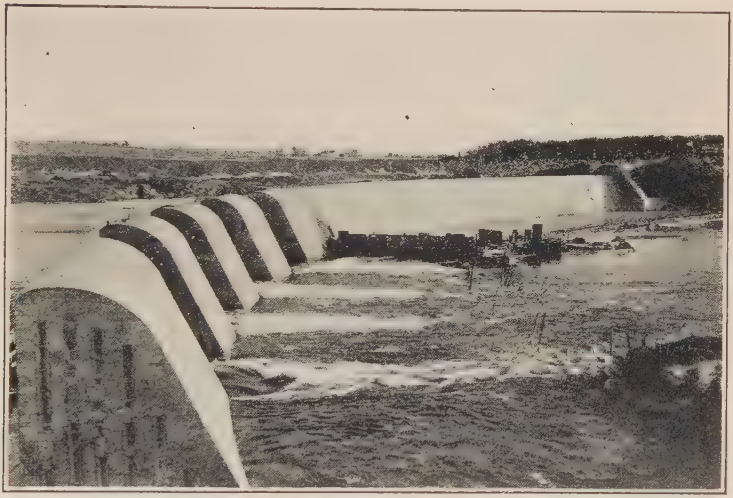

FIG. 7.—CURVED DAM AT CRESCENT. COMPLETED EASTERN END.

at the high lift at Little Falls where the lock is constructed entirely in rock; and at Fulton, on the Oswego River section, the locks are constructed so close to the buildings that they almost become a unit. At Lockport the drop is so sudden that a double lift of a total of 49 ft. is provided by a double lock. At Waterford (Fig. 5) five locks overcome the drop of 170 ft. which is now taken care of by 17 locks.

Adjacent to the locks approach walls are necessary, cut-off walls in earth dams forming pools, and in some cases where the locks are close together there are series of piers for forming docking to keep the barges in the channel. The estimated cost

of these locks with the smaller immediately adjacent structures is $16,000,000. In addition several guard locks are to be provided at various points to prevent loss of a large amount of water in case of accident.

To canalize the rivers it will require 22 fixed dams and 14 movable dams. To one interested in the subject of concrete the fixed dams appeal much more strongly than do the movable dams but to all each has interesting points. The main purpose

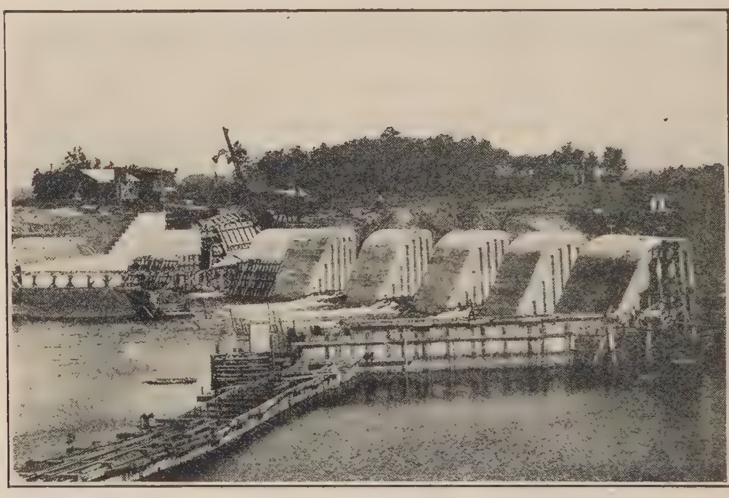

FIG. 8.—CURVED DAM AT CRESCENT—ALTERNATE SECTIONS.

of the movable dams is to take better care of the floods on the rivers than can be done by fixed dams. The movable dams have a point in their favor in that the total cost is less than of the fixed dams, because that in their particular location a shorter length is required than for a fixed dam in order to take care of the flooded waters. The cost of operation is somewhat more but cost of maintenance is the same for both types.

The fixed dams are of particular interest to those interested in concrete. They are all to be built of concrete and their construction is worthy of special consideration. The dam at Vischer's Ferry (Fig. 6) is built in two sections, these being

separated by a rocky island in the middle of the river. The river sections are built on rock bottom while across the island a lighter dam connects the two with a straight crest line 700 ft. long. The concrete in the river sections is massive and it has been advantageous for the contractor to build it of cyclopean masonry. Into this second-class concrete are embedded huge stone—averaging several tons in weight. About 30,000 tons of these large blocks of stone—originally quarried for bridge work —were used in this masonry. The dam is built in sections of 36 ft. in length by 10 ft. high at any one time. Keyways are built in to bind the adjacent sections. The dam has a total length of crest of 1,919 ft.; it has a lock at the southern end and head-gates at the other end. The water is raised 30 ft. by this dam.

The curved dam at Crescent (Figs. 7 and 8) also consists of two sections with a main arched dam, 1,487 ft. in length, an intervening rocky hill and a dam of smaller section across low land which will be flooded when the dam is completed. The total length of this dam, including head-gates, is 1,922 ft. Almost all the other dams have locks but this does not as it marks the eastern end of the canalization of the Mohawk River. The pool back of this dam will be about 28 ft. higher than the present river level. The concrete is also cyclopean. The rocky hill, or ledge, at the site of the dam is an outcrop of a close grained rock. The contractors have opened a quarry here and take the large stone as the basis for the cyclopean masonry. A crusher reduces the small stone to proper size for the concrete. The method of construction is similar to that used on the dam at Vischer's Ferry.

There are, of course, very interesting auxiliary structures with the combined dams and locks, such as headgates, guardgates, retaining walls, core walls into abutting territory and dikes. In addition to the dams necessary for the direct operation of the canal, there are two large storage reservoirs which require large dams.

The Barge Canal calls for the erection of many bridges but these we will not consider except as to the part concrete may play in their construction. The abutments and piers are, of

course, to be made of concrete. The floor system of most of the bridges are to be of reinforced concrete construction. The walks on the bridges are concrete. The interesting feature of the application of concrete to the bridges has been the new and original type of abutments and approaches which have been adopted for the highway bridges. Fig. 9 shows the construction of these abutments and approaches by the use of piers with

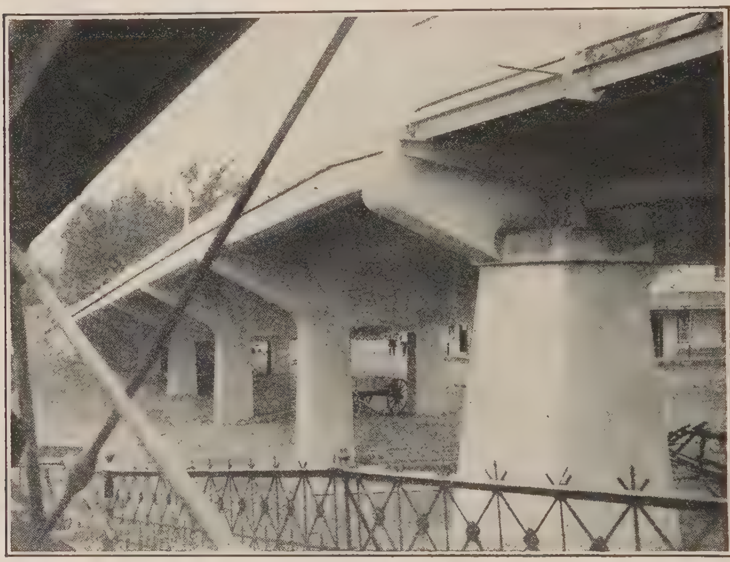

FIG. 9.—APPROACH TO HIGHWAY BRIDGE AT SYLVAN BEACH. REINFORCED CONCRETE AND SLAB CONSTRUCTION.

reinforced beams and floor slabs. The forward piers are of plain concrete built upon a concrete base or wall approximately 25 ft. long by 16 ft. wide and 6 ft. high. These piers carry the highway bridge as well as the short concrete span. The rear piers are made of 24 in. square reinforced concrete columns. By this construction a large amount of concrete is saved over the older form of solid abutment and wing walls, and also a large amount of embankment is saved. The fill is protected by a stone paving on a slope of 1 to 1. It is calculated that, nothwithstanding the larger cost of the reinforced concrete over plain concrete,

a saving of $500.00 is made per single bridge approach span and abutment.

Reference has been made several times to some of the smaller structures. A special statement concerning each of these is hardly necessary as the design and construction is generally characteristic of similar structures on other works. It might be well, however, to call attention to the great saving of concrete that is made on high retaining walls by having recesses in the face of the wall. The same strength is obtained as though the wall were built of solid concrete but quite a saving is made

FIG. 10.—BREAKWATER ON ONEIDA LAKE.

on cost. The breakwaters on Oneida Lake and dikes on river sections are also interesting pieces of work (Fig. 10).

Under the head of testing a reference was made to a proposed concrete arch which is to support the aqueduct carrying the Barge Canal over a gorge at Medina. It is expected that this will be one of the finest, as well as one of the largest concrete arches in the world. The preliminary plans call for a clear span of 285 ft. with a rise of 53 ft. and a total width of 129 ft. There will be a water load of 825 lbs. per sq. ft. and the total load on the arch will be 36,700 tons. It is planned to construct this arch of first-class concrete, being the only large structure to be built of so rich a mixture.

In connection with the development of electric power for the operation of locks and dams, and also the furnishing of electric lighting, it is now being planned to build the power houses of concrete.

THE SURFACE FINISH.

The object has been to secure a good, hard, impervious concrete, and attention in design has been toward economy in construction consistent with practical utility. The surface finish

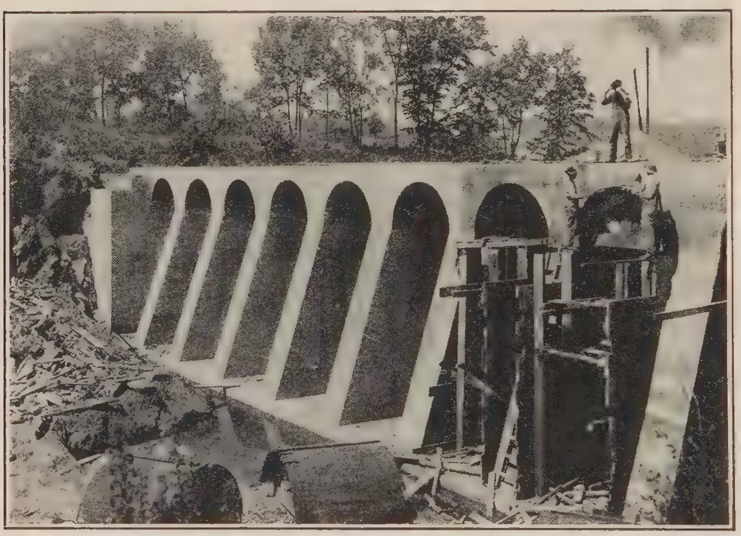

FIG. 11.—HEADGATES ON CRESCENT DAM, SHOWING FINISHED SURFACE.

of the concrete must, however, be pleasing to the eye, and certain requirements are made to produce such a surface. In order to secure a smooth face, the stone is pushed back from the forms by broad-tined forks. For top surface of the coping a mortar, of same proportions and same materials as form the matrix of the concrete, is added to the concrete before it has taken an initial set. The finish is practically that of a sidewalk surface. After the forms are removed from the concrete all exposed faces must be rubbed smooth and hard with a float. A cement grout is used to fill the pits and blow holes, but all projections or

lines must be rubbed down. The result is a smooth face with a uniform color (Fig. 11).

This review of the concrete on the Barge Canal simply calls attention to the fact that nearly all the practical uses of concrete will be made in connection with this vast project. From ordinary sidewalks, to buildings, to massive dams or locks, and to the best kind of reinforced bridge work.

DISCUSSION.

Mr. Gilbreth. MR. F. B. GILBRETH.—If expansion joints were used, how were they made and how was leakage stopped in case it developed?

Mr. Greenman. MR. R. S. GREENMAN.—In the large structures the rule has been to divide them into sections of about 35 or 40 ft. If possible, they are made in alternate sections with keyways in the ends. Before the adjacent section is put in, the faces of the keyways are washed with a pitch compound. The new sections would be molded to fill in the keyways and thus make a joint that prevents seepage.

Mr. Gilbreth. MR. GILBRETH.—I would like to know if any part of this structure has been completed and been in use for a year, if so, did any water leak through the expansion joints?

Mr. Greenman. MR. GREENMAN.—There is one lock completed up in the Champlain section and the gates have only just been put in. I have not heard of any leakage and it was built two seasons ago, remaining in good condition as far as leakage is concerned. It is not expected in the construction of dams to make them absolutely waterproof, but the object is to make the sections fit so well that there will be no joints for the water to get through. There is necessarily a certain amount of leakage and that is all provided for in the storage reservoirs, which take care of any leakage from gates and locks.

The President. THE PRESIDENT.—It might be of interest to learn the probable time of completion of the canal.

Mr. Greenman. MR. GREENMAN.—The canal law was passed in 1893. It took some time to get out the plans, and up to the present I think about $54,000,000 worth of work has been let and about 30 to 40 per cent. of the work has been done. It is figured that during this last year as much work has been done as during the whole period since the law was passed. The rate of increase shows that

the work will be finished about 1915, which is practically within the time originally set. Mr. Greenman.

Up to the present, the cost of the work, which is all done by contract, is quite a little inside of the engineers' estimate. When it is said that a public work estimated at $101,000,000 is going to cost $200,000,000, there is no truth in the matter, judging from the actual and estimated cost of work thus far completed.

THE CONCRETE GROINED ARCH IN FILTER AND COVERED RESERVOIR CONSTRUCTION.

By Thomas H. Wiggin.*

The groined arch for reservoir and filter roofs has been frequently described in good articles (as for example that by Mr. Leonard Metcalf in the Transactions of the American Society of Civil Engineers for 1900, with valuable discussions by W. B. Fuller and others), and the writer's only excuse for this paper is his participation or acquaintance with the design of a number of recent important plants in connection with which fresh consideration has been given to old problems. Incidentally some useful data, mainly drawn from other papers, but extended where convenient, are collected in the paper.

The simple beam, the continuous girder, the simple arch with parallel ends, the retaining wall and the suspension bridge, all handed down to us through generations of empirical engineering and architecture, succumbed a comparatively long time ago to the analysis of the theorist—at least so far as to yield passable hypotheses on which to tabulate the results of experience, thus permitting confident interpolation or extrapolation for new problems. The groined arch, although used centuries ago, remains a purely empirical type of structure, designed, or speaking more accurately, drawn without satisfactory mathematical analysis and used without much knowledge of the factor of safety.

The groined arch has long been used in the architecture of public buildings, probably at least since the second century of the Christian era, but its use in engineering structures has been greatly augmented in the last fifteen years by the advent of the covered slow sand filter plant and its attendant filtered-water reservoir, where the purified water is kept free from the algæ-stimulating sun. To Mr. William Wheeler, of Boston, is due the credit for first using the groined arch in this country in water-

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* Senior Designing Engineer, Board of Water Supply, New York, N. Y.

works construction, the initial plants embodying it being the filters at Somersworth, N. H., and Ashland, Wis.

The reasons other than precedent for this use of the groined arch are in part as follows:

(*a*) Absence of air pockets, thus permitting perfect ventilation.

(*b*) Economy and simplicity—no reinforcement being used for ordinary conditions.

(*c*) Uniform head room both longitudinally and transversely, thus permitting wires for lighting, and pipes or other devices for handling sand to be run level in either direction without waste of head room; also permitting economical lighting.

In 1903 Mr. Leonard Metcalf listed the groined arches in this country with their dimensions and other data, and that list was published in the *Journal* of the New England Waterworks Association, December, 1903, also in the *Engineering News,* December 24, 1903. Table* I is extended from that of Mr. Metcalf's, the additions including, however, only certain of the larger recent works.

The most common form of groined arch roof is one in which the intrados is composed of intersecting semi-elliptical cylindrical surfaces and the extrados of intersecting parabolic cylindrical surfaces. The ellipses and parabolas are generally the same in both longitudinal and transverse arches, but are sometimes different when some special dimension is to be matched in each direction. The floors under piers are generally parabolic groins. The following formulæ for volume of such groins were obtained from Mr. John H. Gregory, who worked them out with Mr. W. B. Fuller while they both were resident at the Albany filter plant for Mr. Allen Hazen.

VOLUMES OF ELLIPTICAL GROINED ARCH UNITS.

m=volume included between intrados, top of pier and plane tangent to intrados at crown.

n = volume of parallelopiped included between planes tangent respectively to intrados and extrados at crown, *i. e.,* t apart vertically.

* Tables I–VI appear on Plate IV, opposite p. 246.—ED.

p = volume included between extrados of arch and plane tangent to extrados at crown.

$v = m + n - p$.

Using Fig. 1* there results:

$$m = 4b\left[cf + \frac{2ad}{3} - \frac{\pi}{4}(cd + af)\right];$$

$$n = 4\,fct;$$

$$p = {}^2/_3\,fch.$$

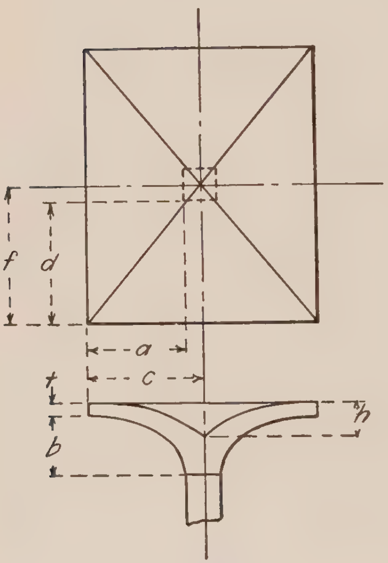

FIG. I.—ROOF.

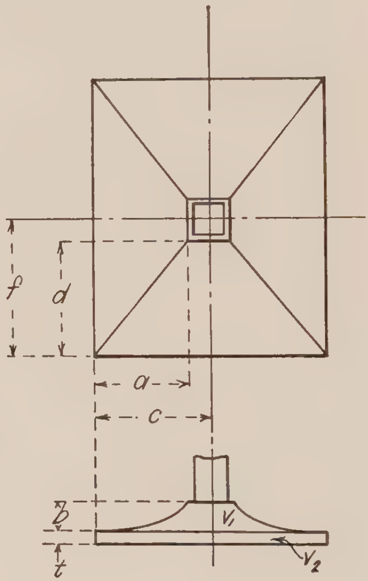

FIG. 2.—FLOOR.

If the groin is square as is usual, $a = d$ and $c = f$ and the formulæ reduce to the following:

$$m = 4b\left[c^2 + \frac{2a^2}{3} - \frac{\pi}{2}ac\right];$$

$$n = 4c^2\,t;$$

$$p = {}^2/_3\,c^2h.$$

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* Acknowledgment for the cuts used in this paper is made as follows: *Engineering-Contracting*, Figs. 1, 2, 4-9, 17, 20; *Engineering Record*, Figs. 16 and 19.—ED.

The floor of filters and covered reservoirs has usually been made of groin units similar to those used in the roof but inverted, having parabolic instead of elliptical intrados, and having a flat instead of parabolic extrados because of resting on the ground. Mr. Gregory's formulæ for volume of such units are as follows (see Fig. 2):

$$V = V_1 + V_2.$$

$$V_1 = 4b\left[cf - \tfrac{2}{3}(af + cd) + \frac{ad}{2}\right]$$

$$V_2 = 4cft.$$

If groin unit is square, that is, if $d = a$ and $f = c$

$$V_1 = 4b\left[c^2 - \tfrac{4}{3}ac + \frac{a^2}{2}\right]$$

$$V_2 = 4c^2t.$$

Diagrams by Mr. Gregory for quickly obtaining with good accuracy the volumes of any arches of given dimensions were published in *Engineering News*, August 23, 1900, p. 131.

Mr. Gregory has also developed formulæ and diagrams for the most economic shape of filter bed for use in sub-dividing a given area of filter surface into units of a given area.* The economy is largely a matter of diminishing length of dividing and marginal walls and is not directly concerned with the roof, which is fixed, except at sidewalls, by total area. There are generally conditions of local topography that fix the layout within rather close limits. Nevertheless it is useful to remember that shape of beds affects economy. In using Mr. Gregory's diagrams it is necessary to obtain the ratio between cost of dividing walls and cost of outside walls per foot. In the latter cost must be included extra filling both for refill and embankment, also extra excavation to permit placing and provide material for the extra embankment. With side walls of aqueduct section in ordinary cases this will result in a ratio of about 1 and the economical shape will have widths 6/10 to 8/10 of lengths if there are six or more beds.

Piers have generally been square but a tendency is notice-

* See *Eng. News*, Oct. 11, 1900, p. 252.

able to make them circular. (See, in order of dates, lines 38, 40, 28, 29, 35 and 41 of Table I.) The circular pier has the advantage in construction that a thin sheet iron form can be used. It also gives a more effective distribution of material in the column. It causes a little complication at its junction with the square base of the roof groin unit but this is not serious as the corners of the roof groin base can be easily chamfered just above the pier by the use of stucco blocks so as to fit the circular top of the pier. Piers of the earlier filters were enlarged by steps, where in the filter sand, to prevent direct passage of the water without proper filtering. The more recent filters have flaring bases but not steps.

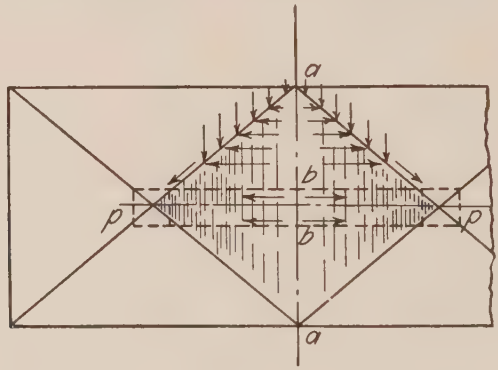


FIG. 4.

Walls of filters have gone through a similar development, batters being used where there were formerly steps.

As many of the problems are applied to the Filtered Water Reservoir at Pittsburgh, Pa., a general plan of same is shown in Fig. 3 (see Plate III, opposite p. 220), Figs. 10-15 illustrating various parts of the work.

METHODS OF DESIGN.

Returning now to the matter of design, there are several methods of considering the groined arch roof as a support for vertical loads:

I. The groined arch is often considered as a series of cylindrical arches (Fig. 4) cut off diamond-shape by the groin lines so that only those parts *bb* opposite the piers are full-centered,

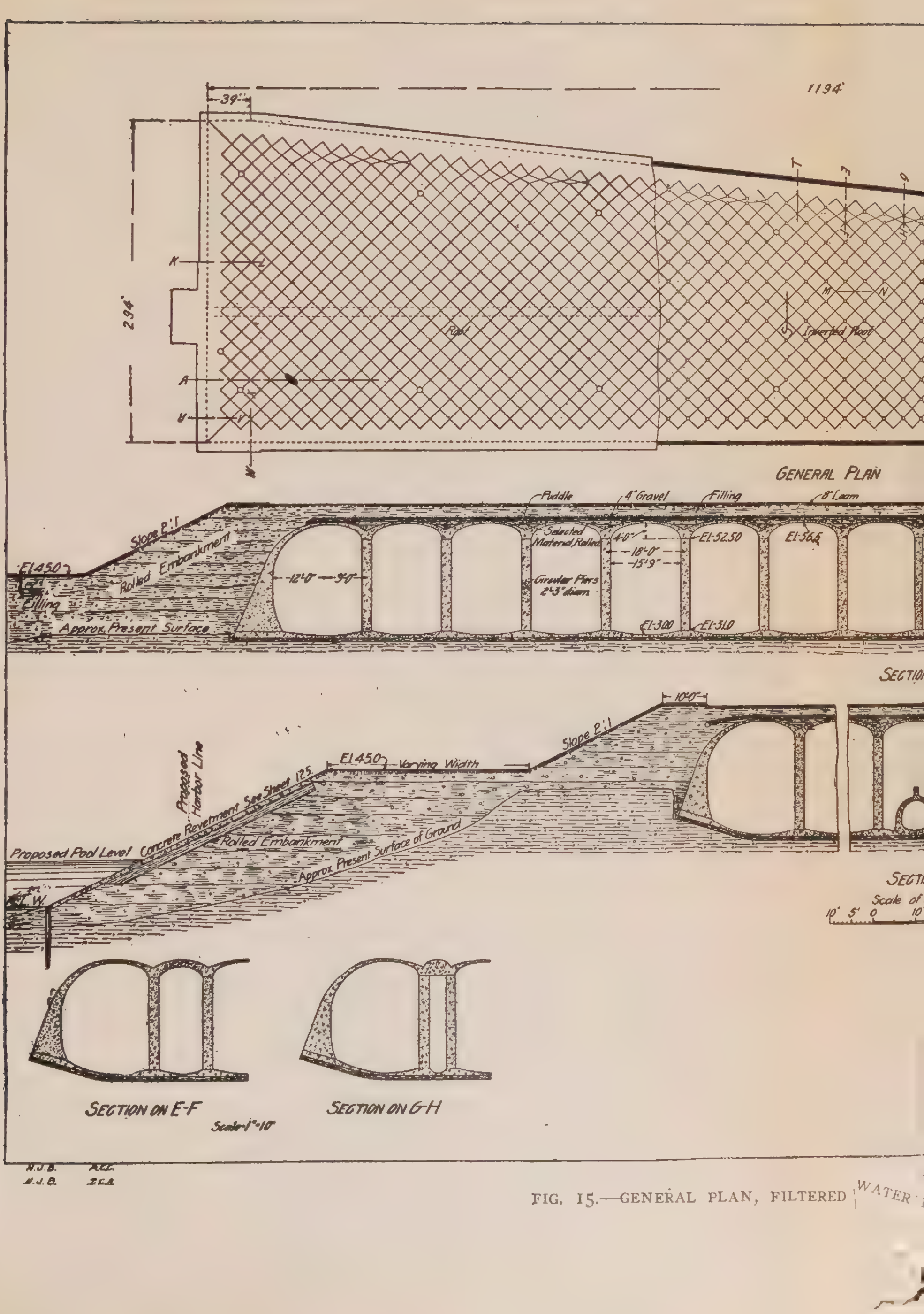
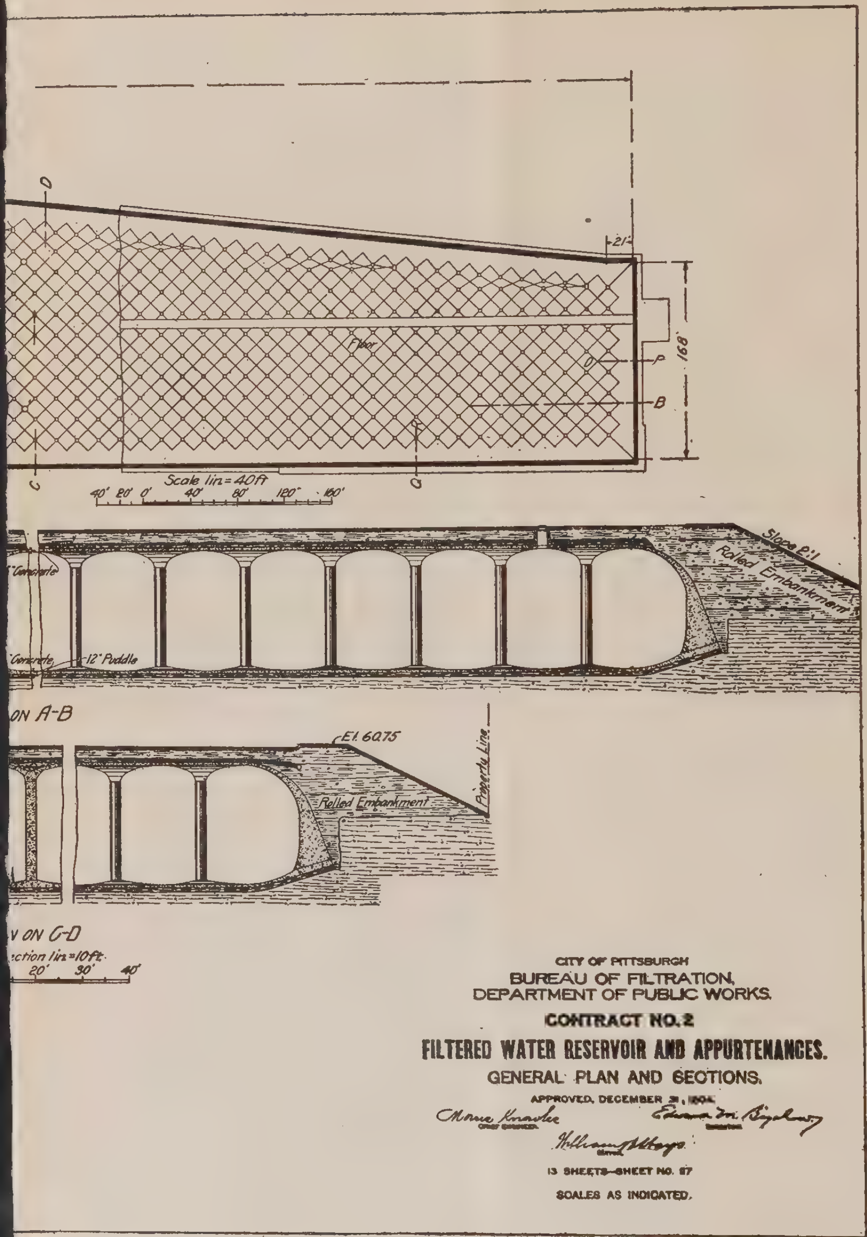


FIG. 15.—GENERAL PLAN, FILTERED WATER



ESER RVOIR, PITTSBURGH, PA.

the balance being segmental of length constantly less as the intersections *a* of groin lines are approached, this length being zero at these intersections. The arch forces traveling down the segmental arches meet corresponding forces from adjacent arches

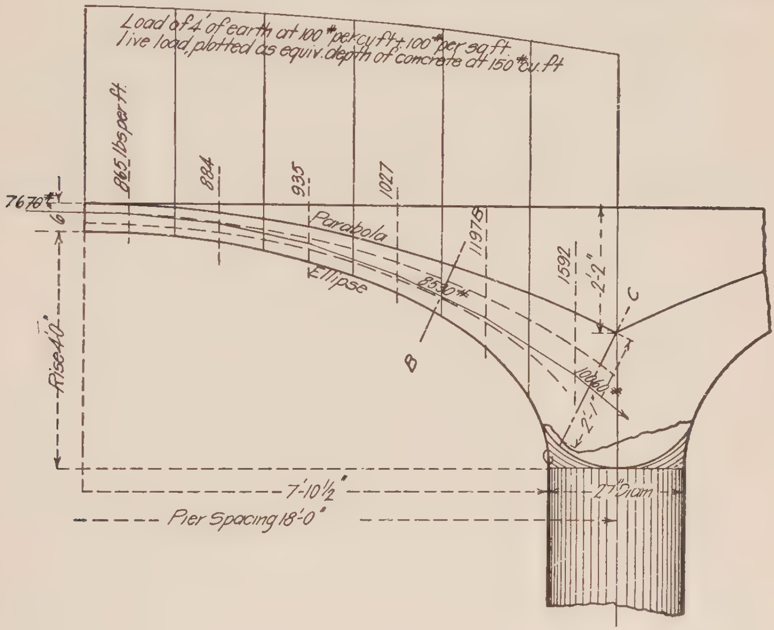


FIG. 5.—METHOD OF COMPUTATION ASSUMING STRESSES SAME AS IN BARREL ARCHES.

(As applied to Filtered Water Reservoir, Pittsburgh,)

TABLE OF STRESSES IN ARCH.

Location of section.	Thrust per lin. ft. of arch.	Area in sq. in.	Av. stress in lbs. per sq. in.	Max. stress in lbs. per sq. in.
Crown........	7,670*	6 × 12	106.5	213
B B..........	8,530	10 × 12	71.	142
C C...........	10,060	25 × 12	33.5	...

*Crown thrust for whole groin unit = 7,670 × 18 = 138,000 lbs.

at the groin lines at an angle of 90 degrees and are supposed to have a resultant acting down the groin line into the pier. This method carries with it the thought that the arch should be thickened along the groin lines *a p* since otherwise there would be no arch to carry the diagonal resultants except what was filched

from the adjacent segmental arches. Architecture has many examples of such thickening along the groin. Many of the engineers who design groined roofs, draw lines of resistance by the methods of graphical statics for the full-centered portion of the arch and assume that the segmental portions take care of themselves somehow down the groin lines without strengthening under the groin. Without an elastic theory for the groined arch it is impossible to compute with any mental satisfaction where the true line of resistance goes, even assuming the rigidity of abutments. Lines of resistance are generally drawn so as to start at the crown at a point distant from the center of thickness

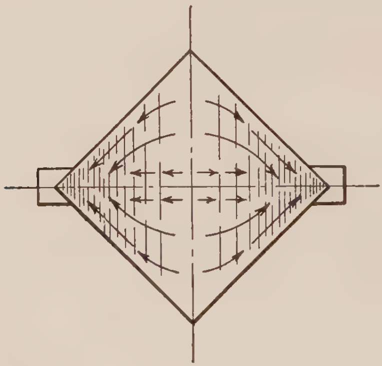


FIG. 6.

by 1/6 that thickness. This results in a maximum compressive stress twice as great as the average, in accordance with the well-known middle-third theory. Fig. 5 shows the result of a line of resistance drawn for the full-centered portions of arch of the filtered water reservoir, Pittsburgh, Pa.

II. The next method is best conceived of if one imagines the arch cut vertically along the groin lines (Fig. 6). The stresses in the segmental portion of the arch are conceived as converging gradually as the pier is approached. Or, in other words, the thrust from the segmental arches is conveyed over gradually to the full-centered part opposite the pier. Fig. 7 shows result by this method applied to the roof of the filtered water reservoir at Pittsburgh, this being comparative with the result of Fig. 5 mentioned

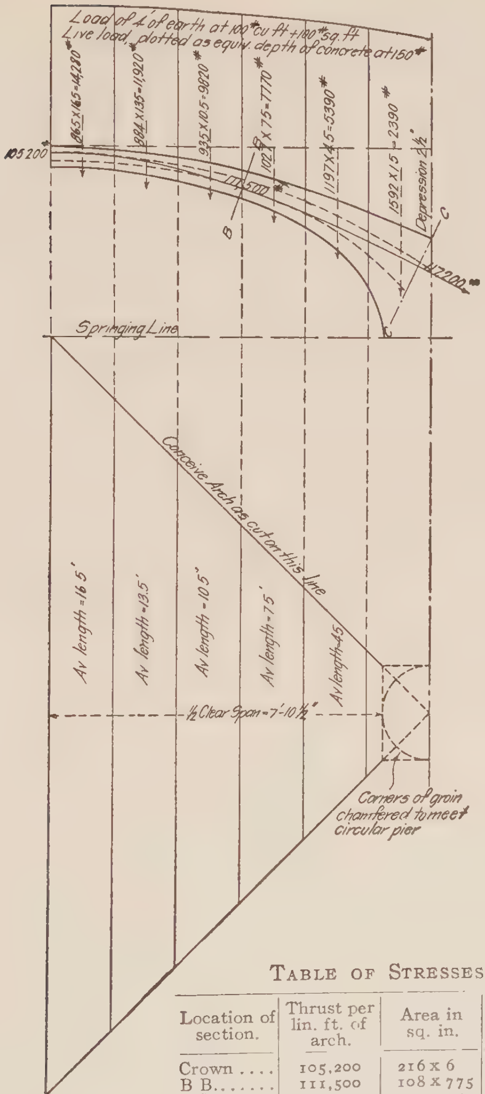


TABLE OF STRESSES IN ARCH.

Location of section.	Thrust per lin. ft. of arch.	Area in sq. in.	Av. stress in lbs. per sq. in.	Max. stress in lbs. per sq. in.
Crown	105,200	216 x 6	81.5	163
B B.......	111,500	108 x 775	133.5	267
C C.......	117,200	27 x 25	174.	348

FIG. 7.—METHOD OF COMPUTATION ASSUMING ARCH CUT ON GROIN LINES.

(Filtered Water Reservoir, Pittsburgh, Computation by M. D. Casler.)

above. The crown thrust is about ¾ as great as in the barrel arch method.

III. The next method consists in considering each square groin unit as a cantilever or inverted dome just as if no bearing existed with the adjacent groin units (Fig. 8). These are really two methods, as the dome idea places the groin unit entirely in tension whereas the cantilever has tension and compression on any vertical or approximately vertical section just as in a beam. The

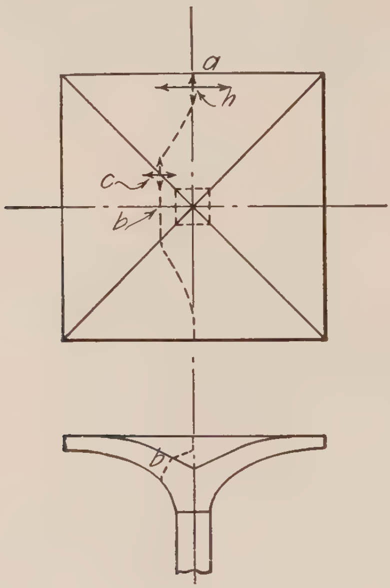


FIG. 8.

concrete in the top of the arch at a point such as *h* would seem to have tension in two principal directions at right angles to each other as shown by the arrows and of intensities having something like the ratio indicated by length of arrows. By the "theory of elasticity" these tensions at right angles would each reduce the effect of the other in rupturing the concrete. Similarly on the under side, the compressions would aid each other. The magnitude of the effect due to similar stresses at right angles is considered as 1/3 or 1/4; for example, a tensile strain in one direction will cause a compressive strain of 1/3 or 1/4 its intensity, in a

direction at right angles, and by that amount will diminish any tensile strain existing or tending to exist in this plane at right angles. The truth of this theory may be seen qualitatively by pulling in two directions on a wide rubber band. At point *a* stress apparently exists only in one direction and at a point like *c* on the groin

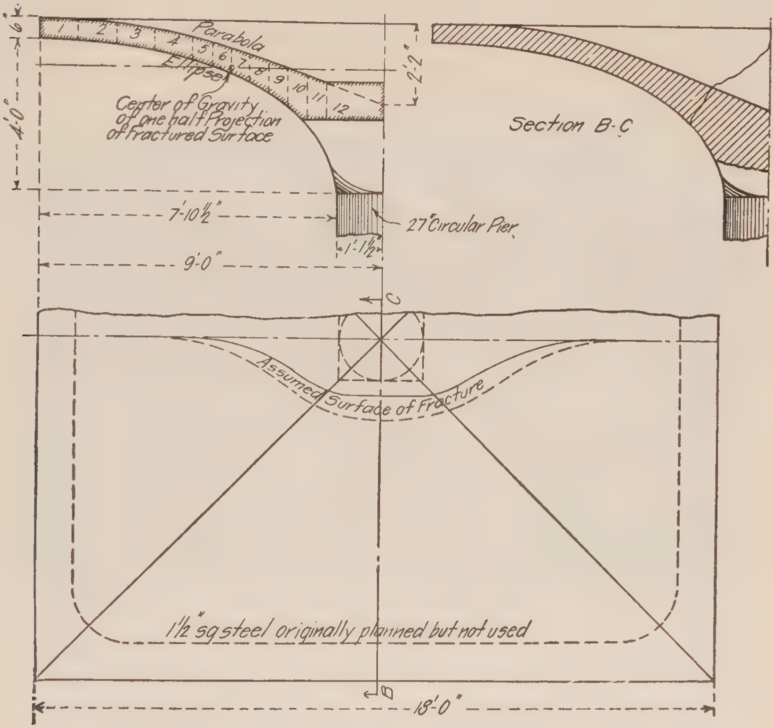


FIG. 9.—METHOD OF COMPUTATION ASSUMING CANTILEVER ACTION. (See Tables II and III.)
(Filtered Water Reservoir, Pittsburgh.)

line equal stresses in each direction would exist. It is hard to see how the reduction in maximum strain could be over 1/6 to 1/8.

As for dome conception the groin unit is not well adapted for such action, being square instead of round and requiring sharp changes of direction in ring stresses at the groin lines. Tests to destruction, made under the writer's direction, of sev-

eral groin units 15 ft. square and standing unsupported on all sides, showed that the initial crack always came at the middle of one of the sides. The weakest section, while not exactly determinable, is probably about as shown by line *a c b a* (Fig. 8). Fig. 9 shows a computation on this cantilever basis of the strength of the groin units of the filtered water reservoir, Pittsburgh. The exact determination of all loads acting on the cantilever and their centers of gravity is too burdensome to be justified in so

FIG. 10.—SCREEDS FOR UPPER LAYER OF FLOOR IN PLACE ON LOWER LAYER OF FLOOR. FILTERED WATER RESERVOIR, PITTSBURGH, PA.

COMPUTATION OF GROIN UNIT AS CANTILEVER.

crude a method. Fairly close approximation can be estimated, however, as will be evident from the following explanations.

The Pittsburgh filtered water reservoir was planned for a filling varying from 4¼ ft. at the road in center down to about 3 ft. at the edges. It has actually only 3 ft. of filling. In Table I, the loading is taken as 3 ft. at 110 lbs. + 15 lbs. of snow, following out Mr. Metcalf's methods; total load, 345 lbs. per sq. ft. On Fig. 9 and Table III, the results are carried out both for the actual loading on the above assumptions and for 4 ft. of

filling at 100 lbs. plus 100 lbs. live load, the latter agreeing more nearly with assumptions used in design and also making the figures comparative with those of Mr. Casler's arch computations given on Fig. 7. The loads and lever arms (see Table I, for general dimensions) referred to the assumed surface of fracture are as follows:

Weight of Concrete.—This is weight of one-half of the groin unit (W_1) less weight of that part at pier within line of fracture (W_2). Average thickness is 8.2 ins. Weight of concrete 150 lbs. per cu. ft.

$W_1 = (8.2 \div)\ (18 \times 9 \times 150)$ 16,600

W_2. (Dimensions scaled from Fig. 9; irregular figure assumed to be a trapezoid.)

Upper base	1.7×6 =	10.2
$4 \times$ mid section	$4 \times 1.6 \times 3.2$ =	20.5
Bottom section	1.125×2.25 =	2.5
		—— 33.2

$W_2 = [(33.2 \times 2.8) \div 6]\ 150 =$ 2,300

Net dead weight outside of surface of fracture...... 14,300

Lever arm (eye estimation) = 3.75 ft. = 45 ins.

Earth Filling in Hollow Over Pier.—Total quantity is 4.34 cu. yds. (See Table I.) From weight of one-half of this (W_1) subtract weight of part within line of fracture (W_2). (Dimensions scaled from Fig. 9; irregular figure assumed to be a trapezoid).

$W_1 = \frac{1}{2} \times 4.34 \times 100$ 5,860

W_2	Upper base	6×1.5 =	9.0
	$4 \times$ mid section	$4 \times 5.6 \times 1.4$ =	31.4
	Lower base	=	0.0
			——40.4

$W_2 = (40.4 \div 6)\ 2.17 \times 100 =$ 1,460

Weight of earth filling in hollow and outside of surface of fracture 4,400

(Second assumption.) Weight of same if assumed at 110 lbs. per cu. ft. 4,800

Lever arm (eye estimation) = $2\frac{1}{4}$ ft. = 27 ins.

Weight of 4 ft. of Earth Filling at 100 lbs. per cu. ft. above

Plane through Extrados at Crown plus 100 lbs. per sq. ft. Live Load.

Outside surface of fracture = $(18 \times 9 - 6 \times 1.5)$ 500 = 76,500

(Second assumption.) 3 ft. of earth filling at 100 lbs. per sq. ft. plus 15 lbs. per sq. ft. snow load = $(18 \times 9 - 6 \times 1.5)$ 345 = ... 52,800

Lever arm estimated at 4 ft. = 48 ins.

The tensile strength at the critical point at the top of the groin may be obtained by the usual formula for beams, $f = My/I$,

where f = the stress desired.

M = the moment, in in. lbs., of the loads.

y = the vertical distance from the center of gravity of the surface of fracture to the point where the stress is desired.

I = the moment of inertia of the surface of fracture. In the computations the projection of this surface is used and lever arms are measured from a point about 1 ft. out from the center of pier. Approximations are unavoidable.

The computations and results are shown in Tables II and III. It will there be seen that the dead load of the concrete alone results in a stress of about 65 lbs. per sq. in., while the 500 lbs. per sq. ft. and 345 lbs. per sq. ft. loadings above the extrados result in 460 and 340 lbs. tension, respectively. It is, therefore, not surprising that the test groin units, standing alone, break of their own weight or with at most a load of 200 lbs. per sq. ft.

EFFECT OF REINFORCEMENT IN GROIN UNIT.

A natural suggestion for reinforcing a groin unit is to place a ring of steel around the unit in the manner indicated in Fig. 9. Such a device was used at Louisville (line 4, Table I). There are several ways of estimating quantitatively the effect of such steel.

I. Consider that it assists the concrete in the upper part of the groin unit in carrying tension. It would then be necessary to add enough metal to bring the tension in the concrete down to a conservative unit, say 50 lbs. per sq. in. The metal could not be

at the very outside fiber ($y = 1.25$), but might be, say, 1 ft. from the center of gravity of the concrete section. The neutral axis would be raised very much if enough metal should be added to the tension side so that the full dead and live loads might be carried with only 50 lbs. tension in the concrete. This would diminish the area of tension concrete and increase the metal needed. But assume, even, that the neutral axis does not rise; the steel would have $(E_s \div E_c)$ $(1 \div 1\frac{1}{4})$ $50 =$ say 500 lbs. per sq. in. tension when the concrete had 50 lbs. There is approximately 3.1 sq. ft. of con-

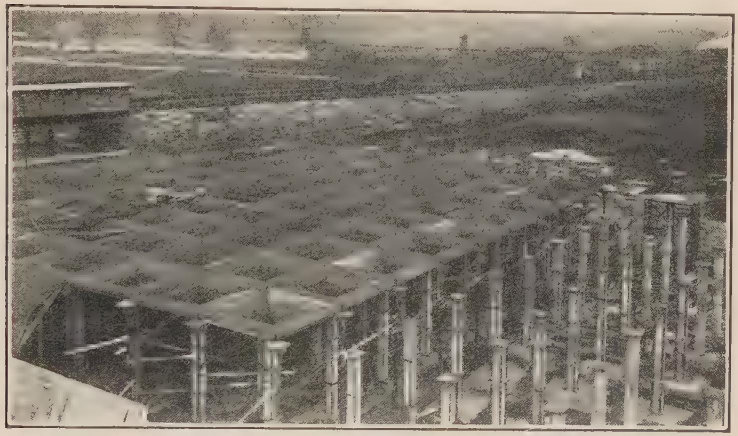


FIG. 11.—FORMS FOR VAULTING. FILTERED WATER RESERVOIR, PITTSBURGH, PA.

crete surface above the neutral axis in the half-section of fracture (Fig. 9) and under the 500 lbs. per sq. ft. loading (see Table III), the tensile stress on it varies from 0 to 460 lbs. per sq. in. or, roughly, 230 lbs. average. To reduce this stress so as to make it vary from 0 to 50 as above assumed, or 25 lbs. average, would require, by this rough method of computing, the quantity of metal, x sq. ft., as shown by the following: $144\ [x \times 500 + (3.1 - x)\ 25] = [31.1 \times 230]\ 144.$ $x = 1.3.$ That is, 1.3 sq. ft. of concrete on the tension side of each half section would have to be replaced by metal to bring the tension in the concrete down to 50 lbs. per sq. in. If proper account were taken of the rising of the neutral axis, the result would be considerably in excess of

1.3 sq. ft., but this result is sufficient to show the absurdity of the conception, which is treated at this length only because it is often assumed that *somehow,* by adding a little metal, joint action will result between the metal and concrete in tension, and at nominal expense make a structure which will stand any abuse safely.

II. Assume that the concrete takes no tension and that the compression on it may be as high as 600 lbs. per sq. in.—*i. e.,* the usual reinforced-concrete beam theory. All warranted accuracy

FIG. 12.—FORMS FOR SQUARE PIERS AND VAULTING. FILTERED WATER RESERVOIR, PITTSBURGH, PA.

in computing the metal by these assumptions will result from estimating the "centroid" of compressive stresses and using the lever arm between this centroid and the metal. For the full groin loading the neutral axis will drop and the centroid likewise from their positions without metal. The centroid without metal is about 1 ft. below the neutral axis and the outer fiber on the compressive side 1.4 ft. Assume 1.15 ft. as the distance of the new centroid; 1.05 ft. is the greatest practicable distance for the metal above the neutral axis. The metal hence has a lever arm of 1.15 + 1.05 = 2.2 ft. For a moment of 4,440,000 in. lbs. the metal would have to

carry $4{,}400{,}000/2 \times 2.2 \times 12 = 83{,}000$ lbs. and of mild steel 5 to 7 sq. ins. would be needed. Tests have shown that lapping such steel is not successful, apparently on account of the thin section of concrete splitting. Such reinforcement is hard to place satisfactorily around the corners, as the extrados is depressed along the groin line so that the steel has to be kept out near the corner and hence turned sharply (see Fig 9). This brings a heavy compressive stress on the concrete at the inside of the curve in the steel. The metal will apparently have about $^2/_3$

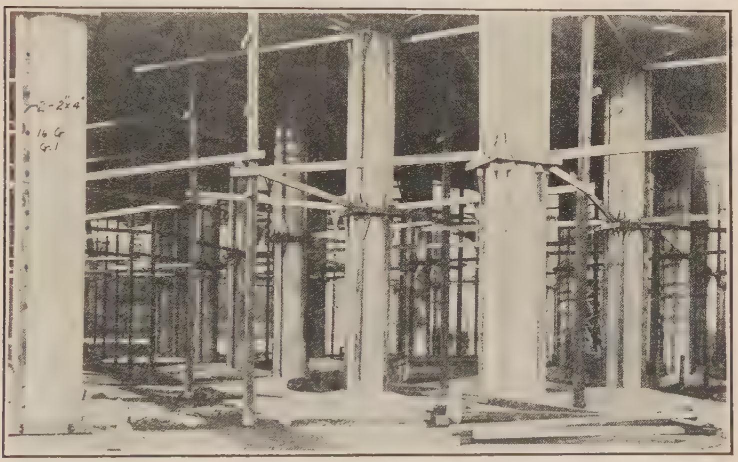


FIG. 13.—FORMS FOR CIRCULAR PIERS AND VAULTING, FILTERED WATER RESERVOIR, PITTSBURGH, PA.

as much tension at the groin lines as at the middle of the sides, or, say, 12,000 lbs. per sq. in. Assume a radius of 18 ins. for a bar 1½ ins. square as in the contract plans of the Pittsburg filtered water reservoir. Further, assume the stress is carried around the corner by uniform radial pressure as in cylinder under hydraulic pressure. $1.5^2 \times 12{,}000 = 27{,}000$ lbs. in the bar. The bearing pressure of the metal against the concrete would then be $27{,}000 \div (1.5 \times 18) = 1{,}000$ lbs. per sq. in.

Enough has been written, the writer thinks, to eliminate cantilever or inverted dome action as the final reliance in carrying load. Arch action is adequate without aid from cantilever action.

SHRINKAGE AND TEMPERATURE CHANGES.

The problem is not so simple as it seems from the foregoing academic discussion of the arch theories. The disturbing elements are two:

(*a*) Shrinkage of concrete in setting.

(*b*) Expansion and contraction of concrete with change of temperature.

Groined arch roofs are usually laid in strips of random length and as they set it is frequently possible to see upward

FIG. 14.—SIDEWALL AND FORMS IN PLACE. FILTERED WATER RESERVOIR, PITTSBURGH, PA.

between the strips. Less shrinkage takes place if sprinkling is faithfully done and the earth covering is put on early.

As for temperature, the concrete will usually be subjected, before the filters or reservoirs are put in service, to extremes from 90 to say 15 degrees F. or lower. This means a change in length of ⅝ in. in every 100 ft., or approximately ⅛ in. for every groin unit. To keep the arch action in those groins in which the concrete cannot endure a high tension in cantilever action (see Table III for magnitude of tension), it is apparently necessary for cracking to occur sufficient to move each side of the groin outward from the pier a distance of about 1/16 in., *less* the

slight movement resulting from the elasticity of the concrete when acting as a cantilever. If this cracking took place along the line of fracture assumed on Fig. 9 it would be visible at the crown on the inside, but probably not elsewhere from the inside without minute examination. Such cracks are occasionally seen, but no one has ever excavated on the outside so far as the writer knows to trace them for their full length. They would exist in their maximum size only in the coldest weather before the reservoir or

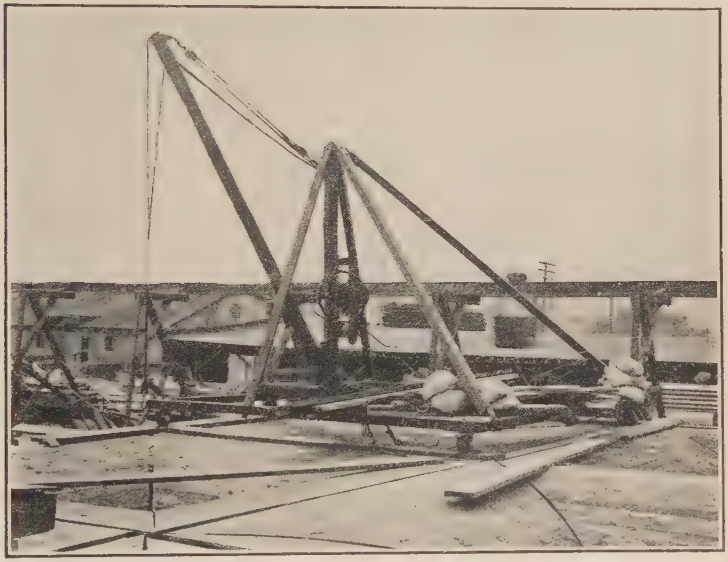


FIG. 15.—MOVABLE DERRICK FOR SETTING VAULTING FORMS.

filter was closed for service. Examinations are not usually made at such times in any unnecessary cases. After the works are in service the temperature would rarely be below 40 degrees F., and lesser cracks only would exist.*

AID GIVEN BY EARTH COVERING.

In all these considerations, one factor has been neglected, viz.: the value of the earth cover. Ordinary earth filling does

* Since writing this the writer has found many evidences that cracking does occur in about the position shown on Fig. 9. These evidences were found in a very few minutes' examination of one filter and a short length of gallery. The cracks are generally straighter than the line of fracture shown on Fig. 9.

not crack with reduced temperature, but more often expands due to freezing of water in the interstices. Mr. F. H. Robbins has pointed out that a very few pounds per square foot in the earth cover would transmit the crown thrusts without help from the concrete. If this action occurred the concrete would be held generally along its top surface by friction and cracks might be distributed. The earth filling the depression would in any case tend to hold the sides of the groin units away from the pier. No proven conclusion on the temperature matter can be drawn except that every groined roof that has not been admittedly maltreated in construction, by allowing the concrete to freeze or pulling the centers prematurely, has stood successfully not only

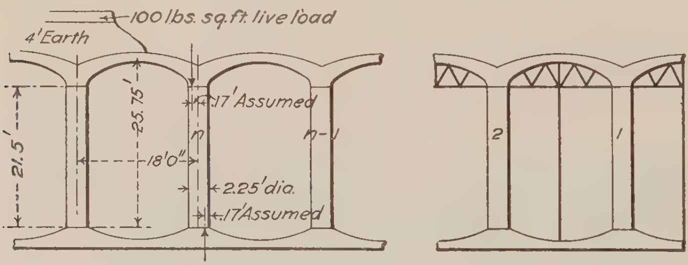


FIG. 16.

its uniform load from fill, but sundry extra loads, such as piles of construction material and heavy concentrated loads hung from the roof by rods. This throws the matter back to the initial proposition of the paper that the theory of groined roofs is incomplete, and the factor, or perhaps better, the margin of safety is uncertain.

CONSTRUCTION STRESSES.

During the construction of groined arch roofs it is occasionally necessary to leave a strip of roof uncompleted so that a space intervenes between the completed roof and the side or end wall of the filter or reservoir. This leaves the groined arches without abutment and at once raises the question as to whether the forms may be removed and earth filling placed also. Construction foremen will tell tales of long edges exposed with the

fill completely placed, but the writer has always been unable to substantiate these statements from the engineers in charge. At the Pittsburgh filters long strips of roof had to be omitted to form lanes through which the cableways could operate, but where filling was to be placed on the roof diagonal bracing was required strong enough to transmit the thrust to the floor: that this bracing was a wise precaution is attested by the fact that in spite of it some of the piers were lifted 1/16 in. or so from their bases on the side away from the braces and another opening took place at the top of the pier. Pictures are shown of teams or moderately heavy rollers going along close to the edge of a void the size of two or three groin units. When it is considered that such loads cover an area of perhaps 50 sq. ft. and are scarcely equivalent in weight to the earth which would be on that small area; further, that the groin is usually entirely free from its earth load in such cases; further, that friction between groins would carry the stress to the groin at the end of the void space, it would be indeed surprising if the arch did not easily endure the load.

It is recognized in construction that earth filling may be safely placed within a reasonable distance, depending on the height of roof, of an incomplete edge of filter or reservoir groined roof and it is pertinent to inquire what the limits of safety are. The only resisting forces are the cantilever action in the groin units and the stability of the piers weighted with their superimposed groins. Two cases may be considered.

Case I. Earth loading on roof terminated abruptly.

Let n = number of empty groins with piers that are necessary to resist the thrust from the loaded portion of roof.

Then for the filtered water reservoir at Pittsburgh (Fig. 16):

Weight of 1 pier $= 3.98 \times 21.5 \times 150 = 12{,}800$ lbs.

Lever arm of pier $= (2.25/2) - .17 = .95$ ft.

Weight of groin unit $= (8.2/12)\ 18^2 \times 150 = 33{,}200$ lbs.

Lever arm of groin unit $= 2.25 - .33 = 1.92$ ft.

(This assumes that there is enough friction and continuity in the roof at the crown points to keep it in its original plane and not permit tipping. Otherwise the lever arm would be only half as great. Observations bear out the assumptions.)

(*a*) Assume thrust as in Fig. 7 = 105,200 lbs.

Lever arm = 21.5 ft.

Then $n\ (12{,}800 \times .95 + 33{,}200 \times 1.92) = 105{,}200 \times 21.5.$

$75{,}9000\ n = 2{,}260{,}000.$

$n = 30.$

That is, it would take 30 groin units and piers or 540 ft. of unloaded reservoir roof, to resist the overturn due to a full load on the adjacent roof. Whatever strength the groin units have as cantilevers, including any effect of continuity of several units, would constitute the only margin of safety. If it were not desired to risk the groins supporting their own weight as cantilevers, it would be necessary to leave the forms under the roof for a sufficient distance from the edge so that the stability of the supported groins would take the thrust from an unsupported unloaded groin. It is customary to thus leave forms in

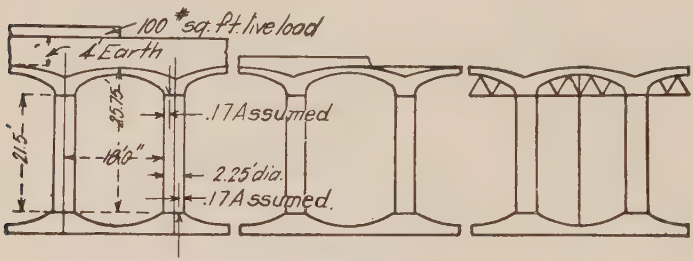


FIG. 17.

place. The number required to be supported by forms will appear from Case II below. It should be noted that any part of the weight of roof that is carried on wooden posts supporting forms is not available to resist overturn. The weights of forms coming on piers may be assumed to offset this deduction.

Case II. Assume earth loading to be tapered off toward the edge (Fig. 17). This will permit full loading nearer the edge than in Case I, since the partial earth loading increases the stability. Even a reasonable estimate under the assumptions requires considerable detailed computation.

Data: (See Case I for certain of results below listed.)

1. Weight of 1 pier	=	12,800 lbs.
2. Assumed lever arm of pier	=	.95 ft.
3. Weight of 1 groin unit	=	33,200 lbs.

4. Assumed lever arm of groined units (also of any loading on groin unit)	=	1.92 ft.
5. Resistance to overturn of 1 pier and groin unit	=	76,000 ft. lbs.
6. Weight of filling in hollow of groin 4.34 cu. yds. at 2,700	=	11,700 lbs.
7. Resistance to overturn afforded by filling of hollow in groin unit = 11,700 × 1.92	=	22,000 ft. lbs.
8. Weight of 1 ft. of filling at 100 lbs. or of 100 lbs. per sq. ft. live load 18 × 18 × 100	=	32,400 lbs.
9. Resistance to overturning afforded by 1 ft. filling = 32,400 × 1.92	=	62,000 ft. lbs.
10. Load on one groin unit due to 4 ft. of filling and 100 lbs. per sq. ft. live load = 500 × 18 × 18	=	162,000 lbs.
Thrust with 500 lbs. sq. ft. load (see Fig. 7)	=	105,000 lbs.

Assumptions:

The thrust of 105,200 lbs. is due to the dead load, earth load and live load roughly in proportion to weight of each load, but is more closely proportioned on the assumption that it is due to

(a) *8/10 of dead weight of groin unit;

(b) ½ of filling in hollow of groin unit;

(c) The whole of filling and live load above plane through extrados at crown.

(The use of 8/10 and ½ the loads in (a) and (b) is due to the fact that a part of weight of groin unit and filling in hollow is concentrated near pier.)

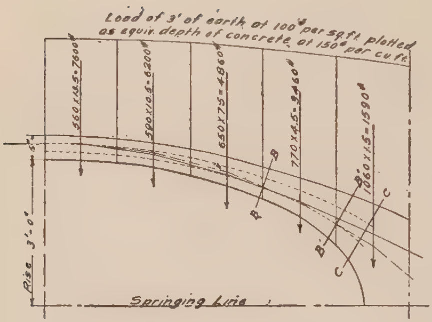
(a_1) 8/10 × 33,200 = 26,600
(b_1) ½ × 11,700 = 6,000
(c_1) 1 × 162,000 = 162,000

194,600 causes thrust of 105,200 lbs.

(a_2) (26,600/194,600) × 105,200 = 14,400 lbs. thrust due to weight of given unit.

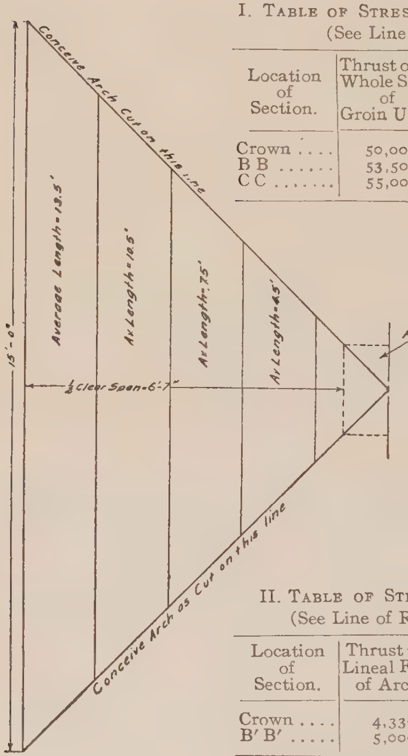
(b_2) (6,000/194,600) × 105,200 = 3,200 assumed to be due to filling in hollow.

*This was fixed to give same thrust, 14,400 lbs., as determined by line of resistance with dead load alone. See (A3) on page 239.



I. TABLE OF STRESSES FOR ARCH TRIANGULAR IN PLAN.
(See Line of Resistance shown in full.)

Location of Section.	Thrust over Whole Side of Groin Unit.	Area of Section, sq. in.	Stress in lbs. per sq. in.	
			Average.	Maximum.
Crown	50,000	6 x 180	46	92
B B	53,500	7.5 x 72	99	198
C C	55,000	15 x 22	167	...



II. TABLE OF STRESSES FOR BARREL ARCH METHOD.
(See Line of Resistance shown in Dashed Line.)

Location of Section.	Thrust per Lineal Foot of Arch.	Area of Section sq. in.	Stress in lbs. per sq. in.	
			Average.	Maximum.
Crown	4,330*	6 x 12	60	120
B' B'	5,000	12 x 12	35	70

*Crown Thrust for Whole Groin Unit = 4330 X 15 = 65,000 lbs.

FIG. 18.—STRESSES IN GROINED ARCHES. (APPLIED TO ROOF OF FILTERS 1–46, PITTSBURGH, PA.)

I. Method assuming arch cut on groin lines.
II. Method assuming stresses same as in barrel arches.

(c_2) $(32{,}400/194{,}600) \times 105{,}200 = 17{,}500$ assumed to be due to each foot of filling or 100 lbs. sq. ft. live load above crown.

(a_3) $14{,}400 \times 21.5 = 310{,}000$ ft. lbs. Overturning moment assumed due to weight of unit.

(b_3) $3{,}200 \times 21.5 = 69{,}000$ ft. lbs. Overturning moment assumed due to filling in hollow.

(c_3) $17{,}500 \times 21.5 = 375{,}000$ ft. lbs. Overturning moment assumed due to 100 lbs. per sq. ft. load.

(d_3) $105{,}200 \times 21.5 = 2{,}260{,}000$ ft. lbs. Overturning moment assumed due to total load.

The computation in Table IV results in permitting the assumed full loading over the 18th pier from the edge. The table

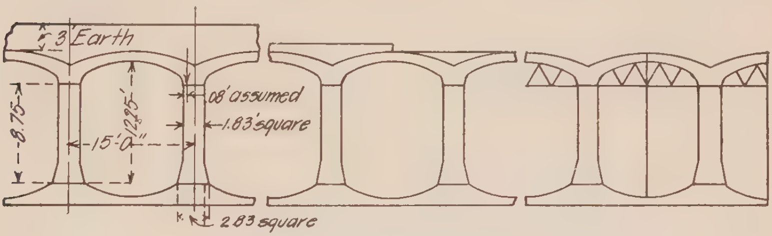


FIG. 19.

shows also that a filling of 3 ft. such as was actually used could be permitted over the 15th or 16th pier. Such relatively elaborate computations and applications of them have not been made in practice so far as the writer knows. Reservoirs of such large area exist at only a few places and the *filter* roofs are more stable by reason of lower and broader-based piers. Dividing walls also introduce stability about every 100 or 200 ft. This is so important a point in construction that a similar determination is given below for the Pittsburgh filters to illustrate the more common problem. Fig. 18 shows the thrust which is 50,000 lbs. per groin unit on the assumption of an arch triangular in plan, as in Fig. 7.

There are two cases to be considered as before. The figure (Fig. 19) is drawn for Case II, but taken in connection with Fig. 16, will be applicable to Case I also.

Data: For Cases I and II. (See also Table I, line 39.)

1. Weight of pier, 35.3 cu. ft. at 150 .... = 5,300 lbs.
2. Lever arm of pier (assumed) .... = 1.33 ft.
3. Weight of one groin unit $15 \times 15 \times (7.3/12$ at 150 .... = 20,500 lbs.
4. Assumed lever arm of groin unit (also of any loading on unit) .... = 2.17 ft.
5. Resistance to overturning of pier + groin unit = $5{,}300 \times 1.33 + 20{,}500 \times 2.17$ .... = 51,000 ft. lbs.
6. Weight of filling in hollow of groin, 2.43 yds., at 2,700 .... = 6,560 lbs.
7. Resistance to overturning afforded by filling in hollow $= 6{,}560 \times 2.17$ .... = 14,000 ft. lbs.
8. Weight of 1 ft. of filling on a groin unit at 100 lbs. .... = 22,500 lbs.
9. Resistance to overturn afforded by 1 ft. of filling $= 22{,}500 \times 2.17$ .... = 48,000 ft. lbs.
10. Weight of 3 ft. of filling on 1 groin unit .... = 67,500 lbs.

Assumptions (as before):

(a_1) $.85^* \times 20{,}500 = 17{,}400$
(b_1) $\frac{1}{2} \times 6{,}560 = 3{,}300$
(c_1) $1 \times 67{,}500 = 67{,}500$

(d_1) 88,200 causes thrust of 50,000 lbs.

(a_2*) $(17{,}400/88{,}200) \times 50{,}000 = 10{,}000$ lbs. thrust assumed due to weight of groin unit.

(b_2) $(3{,}300/88{,}200) \times 50{,}000 = 1{,}900$ lbs. thrust assumed due to filling in hollow.

(c_2) $(22{,}500/88{,}200) \times 50{,}000 = 12{,}800$ lbs. thrust assumed due to 100 lbs. per sq. ft.

(a_3) $10{,}000 \times 8.75 = 87{,}500$ ft. lbs. Overturning moment due to groin unit.

(b_3) $1{,}900 \times 8.75 = 16{,}600$ ft. lbs. Overturning moment due to filling in hollow.

(c_3) $12{,}800 \times 8.75 = 112{,}000$ ft. lbs. Overturning moment due to 100 lbs. sq. ft.

*Adjusted to give same thrust, 10,000 lbs., as a line resistance with dead weight alone.

(d_8) $50{,}000 \times 8.75 = 438{,}000$ ft. lbs. Overturning moment due to total load.

Case I.—Loading terminated abruptly as in Fig. 16.

51,000 n (See Item 5 of "Data" above).

$= 438{,}000$ (See Item d_3 of "Assumptions" above).

$n = 9$, that is, full loading could be placed on arch 135 ft. from edge.

Table V gives the computation for Case II. i. e., the case in which earth loading is assumed to be tapered off as in Fig. 19.

Most of the piers of filters 1 to 46 at Pittsburgh were concreted monolithic with the roof, and hence offered further resistance (as long as the roof acted continuously), to the extent that their strength as cantilever beams permitted. At 50 lbs. per sq. in. in allowable tension, each pier would add resistance, R, computable as follows:

$R \times$ height of springing line $= 1/6 \times 50 \times 22 \times 22 \times 22$.

$R = 88{,}700/8.75 = 10{,}000$ lbs. This is a considerable aid in resisting a thrust of 50,000 lbs. A few piers cracked horizontally at springing.

The various computations above given show the most favorable conditions possible in that they assume continuity of the roof to the extent necessary to bring the roof load on the edge of the pier instead of the center, at the same time bringing the application of the horizontal thrust to the top of the pier instead of the crown of the arch. For winter conditions such assumptions would not be conservative for reasons that will be evident from the early part of the paper.

Reference has been made to bracing unfinished edges of groined roofs where it is desired to fill up to the edge. High roofs, such as that of the filtered water reservoir at Pittsburgh, would be difficult to shore, but the filters are much less so. The most convenient place to shore is opposite each pier, placing the upper end of the brace on the intrados, just above the pier, perpendicular to the intrados, and footing the brace at the base for the next pier. A depression could easily be made for such a brace. Such braces for the Pittsburgh filters are about 17 ft. long and the horizontal protection of their length is about 14 ft., making the load $(17/14) \times 50{,}000 = 60{,}000$ lbs. An 8×10 in. stick of

reasonably good timber with proper bearings at each end is adequate, but blocking at either end with bearing across grain would permit movement and cause cracks to open at the springing line and at the base of the piers. Bracing is certainly more reassuring than a margin of unloaded groins, particularly for work that must stand over winter.

FLOORS OF FILTERS AND RESERVOIRS.

The common form of floors, and methods of computing their volumes is described on page 219. A tabulation of the floors of the various filters and reservoirs would be quite as pertinent and interesting as that for roofs given in Table I. The writer has had time to compile only a few important cases as given in Table VI. The groined arch floor has been as generally satisfactory as the groined arch roof. Groined arch floors are very easily screeded in diamond-shaped pieces joining under piers, along groin lines and along invert lines. The loads on the earth are comparatively light and the thicknesses which have been merely guessed at, so far as the writer knows, have proven adequate. The Pittsburgh filters and reservoirs are mostly on very porous ground and the lower layer of concrete was used in the 1904 design in place of puddle. A standard floor with minimum thickness of 6 ins., as in most other plants, and puddle was the alternative design not used. The 1908 Pittsburg filters contain an innovation in the use of a single flat floor lapping onto reinforced pedestal blocks under piers. The economy in material is evident from the table.

SIDE WALLS AND DIVISION WALLS.

Side walls of filters and reservoirs exhibit the same boldness of design as do the groined arch roofs. They are generally of the so-called aqueduct section, but thinner, particularly at and near the crown, than aqueducts are made. This has an added significance because the side wall is generally concreted separately from the adjacent roof, so as to leave a joint along the crown, whereas the aqueduct is monolithic; and further the side wall has no opposing wall of the same shape and loading to keep a uniform condition,

but instead has against it a long stretch of groined roof with varying temperature conditions. Fig. 20 shows a section of the filtered water reservoir at Pittsburgh, with a half section of the Catskill aqueduct superimposed. At the Washington filtration plant side walls are made like ordinary retaining walls in some cases and the groined arch carried out to them. This gives the same head room near the side walls as near piers or division walls. Dependence must be placed on immobility of filling behind such

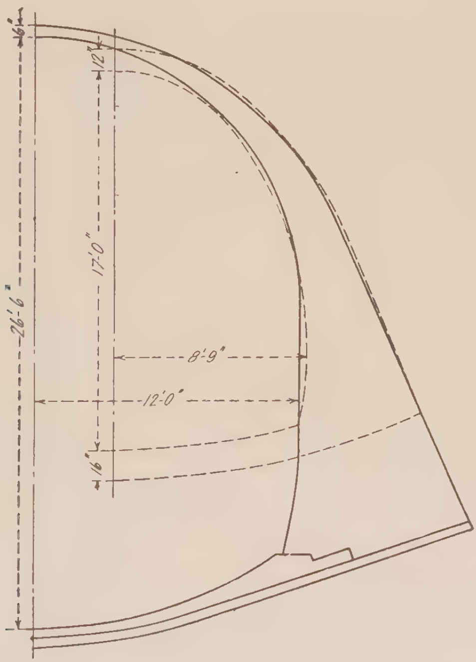
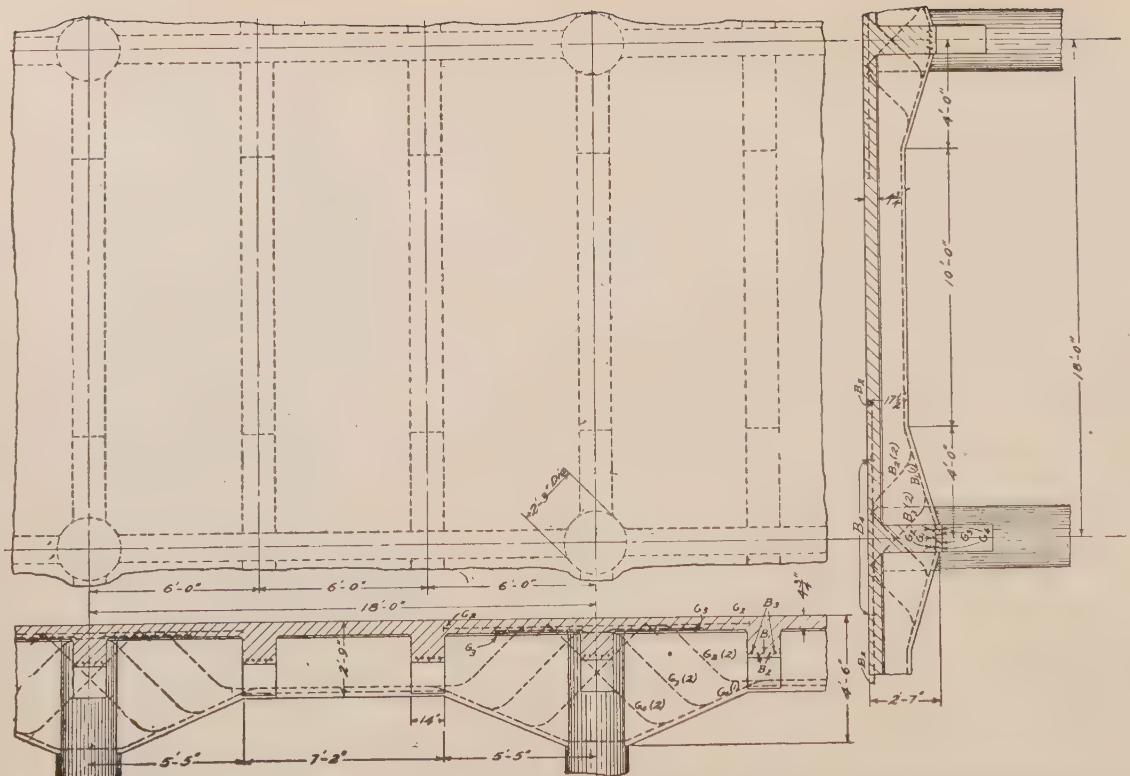


FIG. 20.—DOTTED LINES AQUEDUCT; FULL LINES RESERVOIR.

walls and this dependence appears not to have been misplaced—another example of successful boldness.

Division walls between filters are usually made of the same section as piers, and the floors beneath them are of the same section as the floors beneath piers, though they are sometimes thickened a little.



Assumptions used in Design.

$f_c = 600$.
$f_s = 16{,}000$.
$R = 15$.
Per cent. of Steel $= 0.67$ per cent.
$K = 94$ in formula.
$M = Kbd^2$.
M at Center of Span $= \frac{1}{12}wl^2$.
M over Supports $= \frac{1}{12}wl^2$.

Approximate Quantities.

Concrete — .81 cu. ft. per sq. ft. (average).
Steel — 6.78 lbs. per sq. ft. (average).
Slab reinforcement not shown.

FIG. 21.—APPROXIMATE DESIGN FOR REINFORCED CONCRETE BEAM AND SLAB CONSTRUCTION TO CARRY LOAD OF 500 LBS. PER SQ. FT. IN ADDITION TO DEAD LOAD.

(Made for economic comparison with plain concrete groined arch construction.)

COMPARISON OF GROINED ARCH ROOF WITH REINFORCED CONCRETE SLAB AND BEAM CONSTRUCTION.

(Pittsburgh Filtered Water Reservoir Used as Basis.)

Fig. 21 shows a design for a reinforced floor to carry the same load as that assumed for the groin arch of the Pittsburgh reservoir, viz.: 400 lbs. of earth and 100 lbs. per sq. ft. live load. The units used for the reinforced concrete are as follows:

Compression in concrete................ 600 lbs. per sq. in.
Tension in steel (mild)................. 16,000 lbs. per sq. in.
Ratio of moduli of elasticity 15
Straight line variation in compression of concrete
Moment which beam will carry...................... 94 bd^2
Per cent. of steel.................................. 0.67

Beams and slabs designed for moment of $wl^2/12$ both at center and over supports. Any larger moments due to partial loading assumed to be cared for by increased stresses, since the final conditions are so uniform.

Fig. 21 shows a roughly worked out design for the purpose of comparing costs. No shear computations have been made, but rods are bent up "by eye." The design differs from much of the commercial practice in that the compression in the lower parts of the beams at supports where no slab exists has been provided for by deepening the beams instead of by assuming stronger concrete at these inconvenient points. The downward slope of the bottom of the girders toward their supports is perhaps too abrupt. The girders at supports are not quite deep enough to fulfill the formula 94 bd^2, but there is an excess of steel due to shearing provisions. The slab steel has not been worked out, but the quantity is assumed to be 4/3.4 of the quantity obtained by taking 0.67 per cent. of the volume from the top to the center of steel at the bottom.

From Fig. 21 the average thickness of concrete in the reinforced construction is 9.7 ins. against 8.22 ins. for the groined arch roof of the Pittsburgh reservoir; and the steel and other differences are still to be added. A comparison in more detail is as follows:

Groined arch roof:

8.22/12 cu. ft. of concrete at $6.00 per yd. (22 cts. per ft.) .	$0.15
Charge for forms for each sq. ft.	.10
Total relative cost per sq. ft.	$0.25

Reinforced-concrete roof:

0.8 cu. ft. of concrete at $6.90 per cu. yd. (25.5 cts. cu. ft.) .	$0.207
6.78 lbs. of steel at 2.75 cts.	0.187
Charge for forms for each sq. ft. of roof, say	0.15
	$0.54

The difference in price of concrete is made up of 40 cts. due to using 1:2:4 for the reinforced concrete instead of 1:3:5 as for the groined arch concrete, and 50 cts. assumed extra cost of rehandling or otherwise carefully placing the concrete around the steel. All assumed prices are intended to be so chosen as to favor the reinforced construction, if either. The reinforced construction might be credited with the filling in the hollow of the vaulting not necessary with the flat roof. This would amount to 4.34/324 = .013 yds. of earth filling per sq. ft., but this would cost less than ½ ct. In this comparison it is assumed that the high water line could be at the same distance below the flat roof as below the arched roof and that air pockets formed above high water by the beams are unobjectionable.

It may be objected that it is not fair to compare a reinforced concrete structure capable of bearing, with a certain factor of safety nearly 2 on the elastic limit, a load per square foot of 400 lbs. of filling and 100 lbs. live, with a structure that, whatever it is thought capable of, *is* carrying only perhaps 315 lbs. per sq. ft. in addition to its own weight and doing this with an unknown margin of safety. A sufficiently close correction to the quantities in the reinforced construction resulting from reducing the load to 315 lbs. can be arrived at by assuming that the "effective" concrete and all the steel varies as the square root of the total load, thus:

Table I.—Data on Groined Arch Roofs for Filters and Reservoirs.

First 27 References Compiled by Leonard Metcalf (see Journal of New England Water Works Association, Dec., 1907); Remainder

Reference No.	Date.	Location.	Engineer.	Description.	Depth of Earth Cover, ft. ins.	Concrete Mixed.	Arch. Span, ft. ins.	Arch. Rise, ft. ins.	Crown Thickness, ins.	Depress. over Pier, ins.	Pier Secti[on at] Springing [Line,] Inches = squ[are]
1	1895	Ashland, Wis.	Wm. Wheeler	Filters, net area ½ acre	2 0	1:2½:5	15 9	3 6	6	None	{28 ×23 = / 28½ ×24 =
2	1896	Somersworth, N. H.	Wm. Wheeler	Two filters, total net area ½ acre	2 6	1:2½:5	16 0	4 0	6	None	34½ ×34 =
3	1897	Wellesley, Mass.	Freeman C. Coffin	Reservoir, 80 feet int. diameter	2 0	1:2½:5	12 0	2 6	6	None	24 ×24 =
4	1898	Louisville, Ky.	Chas. Hermany	Res. 154, 739 sq. ft. net. Ar., steel rein. con.	6	1:2:4	19 0	3 9.6	6	27.6	Dia. 3.4' =
5	1899	Concord, Mass.	Leonard Metcalf	Sewage reservoir, 57 ft. int. diameter	2 6	1:2:5	12 9	3 0	6	None	24 ×24 =
6	1899	Albany, N. Y.	Allen Hazen	Filters, 8 beds, 0.7-acre each	2 0	1:3:5	11 11	2 6	6	6	21 ×21 =
7	1899	Clinton, Mass.	F. P. Stearns	Sewage reservoir, 100 ft. int. diameter	4 6	1:2½:4	12 0⅞	2 6	12	None	{30 ×30 = / 25 ×25 =
8	1900	Superior, Wis.	Allen Hazen	Filters and reservoir	2 0	1:3:5	12 0	2 6	6	6	20 ×20 =
9	1901	Phila. Pa., L. Roxborough	John W. Hill	Filters and reservoir	2 0	1:3:5	14 0	3 0	6	21	22 ×22 =
10	1902	Milford, Mass.	Leonard Metcalf	Filters, two of ⅛-acre each	1 6	{1:2½:5 / 1:3:5	14 0	3 0	6	18	24 ×24 =
11	1902	Phila. Pa., U. Roxborough	John W. Hill	Filters and reservoir	2 0	1:3:5	14 0	3 0	6	21	22 ×22 =
12	1902	Natick, Mass.	Frank L. Fuller	Reservoir	2 0	1:2:4½	13 6	2 9	6	None	20 ×20 =
13	1903	Ithaca, N. Y.	Allen Hazen	Coagulant basin and reservoir	2 0	{1:2½:4½ / 1 bbl.9c.f:17c.f	10 6	1 6	6	10½	{18 ×18 = / 17 ×17 =
14	1903	Proposed for Lawrence, Mass.	Morris Knowles	Filter	3 0	....	13 2	2 9	6	18	22 ×22 =
15	1903	Yonkers, N. Y.	Allen Hazen	Reservoir	4 0	1:2.9:5	10 0	1 6	6	9¾	16¾ ×16¾ =
16	1903	Watertown, N. Y.	Allen Hazen	Coagulant basin and reservoir	2 0	1:2.9:5	10 0	1 6	6	10	18 ×18 =
17	1903	Brookline, Mass.	F. F. Forbes	Reservoir, all concrete	2 0	1:2:4	12 0	2 6	6	None	20 ×20 =
18	1903	Phila., Pa., Belmont	John W. Hill	Filters, 18 of 0.74-acre each	2 0	1:3:5	13 5	3 0	6	2	22 ×22 =
19	1903	Phila., Pa., Belmont	John W. Hill	Filtered water basin, 382' ×396'	2 0	1:3:5	14 0	3 0	6	21	22 ×22 =
20	1903	Phila., Pa., Torresdale	John W. Hill	Filters, 33 of 0.75-acre each	2 0	1:3:5	14 0	3 0	6	21	22 ×22 =
21	1903	Phila., Pa., Torresdale	John W. Hill	Filters, 22 of 0.75-acre each	2 0	1:3;5	13 2	3 0	6	21	22 ×22 =
22	1903	Phila., Pa., Torresdale	John W. Hill	Filtered water basin, 602' ×762'	2 0	1:3:5	14 0	3 0	6	21	22 ×22 =
23	1903	Washington, D. C.	Col. A. M. Miller	Filters Nos. 1 to 24	2 0	1:2.9:5	12 2	2 6	6	17	22 ×22 =
24	1903	Washington, D. C.	Col. A. M. Miller	Filters Nos. 25 to 29	2 0	1:2.9:5	11 10	2 6	6	17	22 ×22 =
25	1903	New Milford, N. J.	Hering & Fuller	Clear water well under mech. filters	None	....	{9 8 / 11 8	2 6	8	None	24 ×24 =
26	1903	New Milford, N. J.	Hering & Fuller	Clear water well under mech. filters	None	....	{11 8 / 12 0	2 6	8	None	24 ×24 =
27	1903	Washington, D. C.	Col. A. M. Miller	Pure water reservoir	2 0	1:2:9:5	15 6	3 6	6	24¾	30 ×30 =
28	1907	Wilmington, Del.	Theo. A. Leison	Filters, 6 of 0.6-acre each	2 0	....	13 6	3 0	6	21	Dia. 24 =
29	1907	Wilmington, Del.	Theo. A. Leison	Filtered water reservoir	2 0	....	13 6	3 0	6	21	Dia. 24 =
30	1903	N. Y. C., Stormville	Wm. B. Fuller	Filters, 200 of 0.97-acre each (proposed)†	2 0	1:3:5	{15 0 / 15 10	3 4	6	22	20 ×20 =
31	1903	N. Y. City, Hillview	Wm. B. Fuller	Filtered water reservoir (proposed)†	2 4	1:3:5	20 0	4 0	6	22	Dia. 28 =
32	1906	Columbus, Ohio	Julian Griggs	10 filters and reservoirs	None	1:2½:5½	{12* 10 / 10 0	*2 3	* 8	None	*20 ×20 =
33	1905	Cincinnati, Ohio	G. H. Benzenberg	Supports for 28 filters of 0.4-acre each	8	....	{9 5¾ / 11 0	2 6	8	None	21 ×21 =
34	1907	Jerome Park, N. Y.	I. M. De Varona	Filters, 104 of 0.4-acre each	2 0	....	13 9	2 0	6	*18	18 ×18 =
35	1907	Jerome Park, N. Y.	I. M. De Varona	Filtered water reservoir	2 0	....	18 0	4 6	6	*21	Dia. 24 =
36	1906	Providence, R. I.	Ottis F. Clapp	Filters	2 0	....	10 4	2 6	6	15	20 ×20 =
37	1907	New Orleans, La.	Geo. G. Earl	Two filtered water reservoirs	1 0	....	10* 9	2 6	6	*15	15 ×15 =
38	1901	Pittsburg, Pa.	Morris Knowles	Filtered water reservoir	2 0	1:3:5	13 9	3 0	6	12	Dia. 27 =
39	1904	Pittsburg, Pa.	Morris Knowles	Filters, 46 of 1 acre each	3 0	1:3:5	13 2	3 0	6	21	22 ×22 =
40	1904	Pittsburg, Pa.	Morris Knowles	Filtered water reservoir	3 0	1:3:5	15 9	4 0	6	26	Dia. 27 =
41	1908	Pittsburg, Pa.	Morris Knowles	Filters, 10 of 1 acre each	2 3	1:3:5	13 2	3 0	6	21	Dia. 20 =
42	1908	Springfield, Mass.	Elbert E. Lochridge	Filters, 6 of 0.52-acre each	2 0	....	11 4	2 0	6	15	20 ×20 =
43	1908	Springfield, Mass.	Elbert E. Lochridge	Filtered water reservoir	2 0	....	14 0	2 9	6	18	24 ×24 =
44	1909	N. Y. City, Hillview	J. Waldo Smith	Filtered water reservoir (proposed)†	(18" to 3')	1:3:5	19 2	5 0	6	31	Dia. 34 =

*Note: These dimensions were scaled. †Will not be built. §For explanation see Mr. Metcalf's article.
[1]Cost column covers cost masonry only from springing line of roof. Earth cover and engineering not included unless so stated.
[2]Earth cover, etc., included total exclusive engineering only (10 per cent. ±). See text. Steel reinforcement.
[3]Including filling, manholes, etc., but excluding engineering.
[4]Cost per square foot is estimated from force accounts. Contractor's price was less. (Poor management.)

[5]Including sand stored upon
[6]Four-fifth of clear well with
[7]One-fifth of clear well with
[8]Carries filters. About 1,1
directions.
[9]Cost includes concrete and

Table II.—Computation of Moment of Inertia of Assumed Surface of Fracture. (See Fig. 9.)

No. of section.	b.	h.	I_0.	a.	g.	ag^2.
1	1	52	.012	.52	1.0	.52
2	1	.53	.012	.53	.90	.43
3	1	.55	.014	.55	.78	.34
4	1	.57	.015	.57	.60	.21
5	.5	.61	.009	.30	.40	.05
6	.5	.65	.011	.33	.25	.02
7	.5	.70	.014	.35	.08	.0
8	.5	.80	.021	.40	.10	.0
9	.5	.90	.030	.45	.40	.07
10	.5	1.1	.055	.55	.63	.22
11	.5	1.05	.048	.53	.75	.30
12	1.5	1.02	.125	1.53	.82	1.01
Total	...	....	.366	....	....	3.17

Explanation: $I_0 = 1/12\ bh^3$; g = distance from c. of g. of small section to neutral axis.

I for half section: $I = \Sigma I_0 + \Sigma ag^2 = .37 + 3.17 = 3.54$ (all dimensions in feet).

I for whole section: $I = 2 \times 3.54 \times 12^4$ (all dimensions in ins.).

Table III.—Loads, Moments and Maximum Tensile Stresses for Line of Fracture Shown. (See Fig. 9.)

No. of line.	Load. Description.	Load. Weight.	Assumed lever arm, ins.	Moment in 1,000 in. lbs.	Max. tensile stress due to Mom. $f = \frac{My}{I}$.
1	Concrete	14,300	45	640	...
2	Earth filling below crown at 100 lbs. per cu. ft.	4,400	27	120	65
3	Earth above crown: 4 ft. at 100 lbs. per cu. ft. + live load at 100 lbs. per sq. ft. Total load = 500 lbs. per sq. ft.	76,500	48	3,680	...
4	Total for 1 + 2 + 3	......	....	4,440	
5	Earth filling below crown of 100 lbs. per cu. ft.	4,800	27	130	460
6	Earth above crown: 3 ft. at 110 lbs. per cu. ft. + 15 lbs. snow. Total = 345 as per table of groined arches	52,800	48	2,540	340
7	Total for 1 + 5 + 6 as per table of groined arches	......	....	3,310	....

* Reference No.	Date.	Location
6	1899	Albany, N. Y.
9	1901	Phila, Pa, Low. Ro
11	1902	do. Upper Roxbo
18	1903	Philadelphia, Pa.,
19	1903	Philadelphia, Pa.,
20	1903	Phila., Pa., Torres
21	1903	Phila., Pa., Torres
22	1903	Phila., Pa., Torres
23	1903	Washington, D. C.
30	1903	†N. Y. City, Storm
31	1903	†New York City,
39	1904	Pittsburg, Pa.
40	1904	Pittsburg, Pa.
41	1908	Pittsburg, Pa.
44	1909	‡New York City,

* Same as in Table I.
† Not built.
‡ To be built without
§ Two layers of concr
‖ Bottom of floor und
high, or an average of 2 i
¶ Pier foundation 6
for 4×12-in. water stops
x Design for Rock.

…apiled by Morris Knowles and T. H. Wiggin.

…et.	Vol. Saved by Depress. in cu. yds. and Eq. Dph. in cu. yds. ins.	Mean Thick-ness of Roof ins.	Cost[1] per sq. ft., dollars.	Pier Load, tons per sq. ft. above Springing Line, Concrete at 150 lbs., Brick 130, Earth 110, and Snow 15.	Intrados§ R = $\frac{(\text{Span})^2}{8\times\text{Rise}}\pm$ Feet.	Intrados§ R = $\frac{(\text{Semi-Span})^2+(\text{Rise})^2}{2\times\text{Rise}}$ Feet.
	None	11.7	....	12.5	8.9	10.6
brick						
gran.	None	13.0	0.47	9.7	8.0	10.0
rick.	None	10.3	0.225	8.9	7.2	8.5
	5.45=3.7	11.7	0.61[2]	5.8	(11.9)	(13.8)
rick.	None	11.0	0.38	11.7	6.8	8.3
brick.	0.93=1.63	8.5	{0.182	11.0	7.1	8.4
			{0.277[3]			
	None	16.8	....	12.2}	7.3	8.5
brick.				17.7}		
brick.	0.93=1.63	8.4	0.29	12.0	7.2	8.5
	2.70=3.5	7.3	....	13.3	8.2	9.7
	2.37=3.0	7.9	0.36[4]	9.8}	8.2	9.7
				16.8}		
	2.70=3.5	7.3	....	13.3[5]	8.2	9.7
	None	10.4	0.40	15.1	8.3	9.7
	0.75=1.70	6.78	....	10.9&12.2	9.2	9.9
	2.08=3.0	7.5	....	15.6	7.9	9.2
	0.65=1.6	7.0	....	18.5	8.3	9.1
	0.68=1.7	6.9	....	9.9	8.3	9.1
	None	10.1	0.40±	12.2	7.2	8.4
	2.51=3.5	7.3	....	12.4	7.5	9.0
	2.70=3.5	7.2	....	13.3	8.2	9.7
	2.70=3.5	7.2	....	13.3	8.2	9.7
	2.48=3.5	7.4	....	12.0	7.2	8.7
	2.70=3.5	7.2	....	13.3	8.2	9.7
	1.70=2.8	7.3	0.31+	9.7+sand stored	7.4	8.6
	1.63=2.8	7.4	0.31+	9.1+sand stored	7.0	8.2
	None	11.7	....	30±	{4.7	{5.9[6]
					{6.8	{8.1
	None	12.3	....	30±	{6.8	{8.1[7]
					{7.2	{8.4
	4.0=1.5	7.9	0.31+	8.7+storage	8.6	10.3
	2.59=3.5	7.4	....	13.78	7.6	9.1
	2.59=3.5	7.4	....	13.78	7.6	9.1
	3.3=3.7	7.3	....	18.7	{8.4	{12.5
					{7.5	{10.4
	5.64=3.6	8.5	....	24.04	10.1	14.5
	None	.....	....	.....	{9.1	{10.2
					{5.5	{6.6
	None	12	....	About 29	{4.5	{5.75
					{6.0	{7.3[8]
	2.15=2.7	6+	....	18.91	12.6	9.0
	4.28=5.0	9.2	....	22.40	12.5	11.2
	1.02=2.3	7.7	....	8.72	7.4	13.3
	1.11=2.5	6.2	....	9.83	5.7	7.0
	1.58=2.0	9.0	....	11.8	7.8	9.4
	2.43=3.4	7.3	.189	15.7	7.2	8.7[9]
	4.34=4.3	8.2	.204	17.6	7.7	9.7[9]
	2.38=3.5	7.3	.276	19.4	7.2	8.7[9]
	1.30=2.5	6.6	....	9.65	8.0	8.9
	2.36=3.0	8.5	....	10.52	8.5	10.3
	9.25=6.2	8.22	....	13.1 to 19.4	9.2	11.7

…f.
…se arches.
…e arches.
…s. per sq. ft. Reinforced with ⅜-in. square twisted bars, spaced 12 ins. in both
…ring for bay without ventilator.

TABLE IV.—COMPUTATION OF SAFE LOADING ON ROOF OF FILTERED WATER RESERVOIR, PITTSBURGH, ADJACENT TO AN UNFINISHED EDGE OF ROOF. CASE II. FILLING TAPERED AS IN FIG. 17.

No. of pier and groin.	*Resistance to overturning, 1,000 ft. lbs.	Total resistance to overturning, 1,000 ft. lbs.	Safe loading on next groin unit. (For thrusts, see Assumptions on p. 237.)
1.	2.	3.	4.
1 to 5 inc.	Each 76	380	Own weight (a_3) 310
6	76	456	Own weight 310 Filling in hollow (b_3) 69 379 459—379= 77÷$\frac{77}{†375}$= .20′ fill over crown.
7	Own weight 76 Fill in hollow 22 .20×62= 12 110	566	566—379= 187÷$\frac{187}{375}$= .50′ fill over crown.
8	.76+22= 98 .50×62= 31 129	695	695—379= 316÷ .84′ fill over crown.
9	98 .84×62= 52 150	845	845—379= 466÷ 1.24′ fill over crown.
10	98 1.24×62= 77 175	1,020	1,020—379= 641÷ 1.71′ fill over crown.
11	98 1.71×62= 106 204	1,224	1,224—379= 845÷ 2.25′ fill over crown.
12	98 2.25×62= 140 238	1,462	1,462—379=1,083÷ 2.90′ fill over crown.
13	98 2.90×62= 180 278	1,740	1,740—379=1,361÷ 3.65′ fill over crown.
14	98 3.65×62= 225 323	2,063	2,063—379=1,684÷ {4.00′ fill over crown. +50 lbs. per sq. ft. live load.
15	98 4.50×62= 280 378	2,441	2,441—379=2,062÷ {4.00′ fill over crown +150 lbs. per sq. ft. live load.

* See Items 5, 7 and 9 of Data. † See Item C_3.

TABLE VI.—DATA ON FLOORS OF A FEW FILTERS AND RESERVOIRS.

	Engineer.	Pier spacing, ft.	ins.	Size of base on which pier rests, ins.	Thickness under pier, ins.	Thickness at invert, ins.	Av'age thickness, ins.	Thickness of puddle, ins.	Kind of soil.	
....	Allen Hazen......	13	8	30x30	15	6	8.2	0	.....	Filters.
…gh..	John W. Hill.....	15	10	36x36	14	6	8.0	12	.....	Filters and reservoir.
.....	"	15	10	36x36	14	6	8.0	12	.....	Filters and reservoir.
…t....	"	15	3	36x36	14	6	8.1	12	.....	Filters and reservoir.
…t...	"	15	10	24x24	14	6	7.7	12	.....	Filtered water res.
....	"	15	10	36x36	14	6	8.0	12	.....	33 filters.
....	"	15	0	36x36	14	6	8.1	12	.....	22 filters.
....	"	15	10	24x24	14	6	7.7	12	.....	Filtered water res.
..	Col. A. M. Miller..	14	0	32x32	15	6	8.2	0	.....	Filters 1-24.
....	Wm. B. Fuller.....	17 6x16	8	36x36	16	8	§10.0	0	Rock, hardpan	200 filters.
....	"	22	4	30x30	24	12	§14.5	0	xRock.	Filtered water res.
.	Morris Knowles...	15	0	36x36	17	8	§10.4	0	Mostly silt.	Filters 1-46.
	"	18	0	27x27	22	10	§12.6	0	Sandy gravel.	Filtered water res.
.....	"	14	10	——	¶ ——	——	6.6	0	Sandy gravel.	Filters 47-56.
…w...	J. Waldo Smith...	22	0	36x36	‖18	6	‖ 8.0	0	Hardpan.	Filtered water res.

…and with flat floor—above design abandoned.
…stead of one layer of concrete and puddle.
…r is 6 inches higher than bottom under invert, thus saving a pyramid of excavation and concrete 22×22 ft.×6 ins.
…ver whole area. Excavation somewhat complicated. Done to improve drainage of excavation under piers.
…/ 12 ins. thick, reinforced with 16 ¾-in. square steel bars. (Total weight=126 lbs.) Rest of floor 5 ins. thick, except
…diagonal joints.
…now known not to exist.

TABLE V.—COMPUTATION OF SAFE LOADING ON ROOF OF FILTERS 1 TO 46 AT PITTSBURGH, PA., ADJACENT TO AN UNFINISHED EDGE OF ROOF. CASE II. FILLING TAPERED AS IN FIG. 19.

No. of pier and groin.	*Resistance to overturning, 1,000 ft. lbs.	Total resistance to overturning, 1,000 ft. lbs.	Safe loading for next groin unit. (For thrusts see Assumptions on p. 240.)
1.	2.	3.	4.
1 to 3 inc.	Each 51	153	{Own weight (a_3) 87.5 ft. lbs. Filling in hollow (b_3) 15.5 ft. lbs. 104 ft. lbs. 153—104= 49÷$\frac{49}{†112}$= .44′ fill above crown.
4	Own weight 51 Fill in hollow 14 .44×48 21 86	239	239—104=135÷$\frac{135}{112}$=1.20′ fill above crown.
5	51+14= 65 1.2 ×48= 58 123	362	362—104=258÷$\frac{258}{112}$=2.30′ fill above crown.
6	65 2.3 ×48= 110 175	537	537—104=433÷$\frac{433}{112}$=3.9′ fill above crown.

* See Items 5, 7 and 9 of Data. † See Item C_3.

Result indicates that full depth of filling could be placed on the seventh row of groin

Loads as used in design—Dead load		120 lbs. per sq. ft.
	Live load	500 lbs. per sq. ft.
		620
Revised loads.............Dead load say		105 lbs. per sq. ft.
	Live load	315 lbs. per sq. ft.
		420

Effective concrete say 8/10 of total.

Then revised effective concrete =

$$\sqrt{\frac{420}{620}} \times 8/10 \times .81 = .53 \text{ cu. ft. per sq. ft.}$$

Revised total concrete = $.53 + 1/5 \times .81 \ldots = .70$ cu. ft. per sq. ft.

Revised steel quantity = $\sqrt{\frac{420}{620}} \times 6.78 \ldots = 5.6$ lbs. per sq. ft.

Revised relative cost = $.70 \times \$0.255 + 5.6 \times \$0.0275 +$ say $\$0.14 =$ $0.47 per sq. ft.

Again it may be said that it is not necessary to space the piers so far apart. The cost of the effective concrete and the steel would be reduced approximately in direct ratio of the revised to the original span. But the saving computed by reducing the span would be more apparent than real since the high piers are already about as slender as desirable and the cost of forms per square foot of roof would probably increase with the greater number of units to be erected to produce the given area of roof. One who has watched the extremely rapid work of placing the groined roof by cableway (an average of 200 cu. yds. per day has been placed with one cableway during several months) would probably never feel moved to substitute, at least on a large plant, the complicated reinforced construction, even if the factor of safety of the groined arch is a little obscure. The New Haven filter plant is an example of the use of reinforced concrete for a small plant.

In conclusion the writer wishes to make acknowledgment to Mr. Morris Knowles, Chief Engineer of the Bureau of Filtration, Pittsburgh, Pa., for permission to use the Pittsburgh work as a text and for making it possible to insert Figs. 3 and 10-15 from the progress photographs taken during the construction of the Pittsburgh plant by the T. A. Gillespie Co., and illustrating the common methods of construction.

A SIMPLE METHOD OF COMPUTING THE STRENGTH OF FLAT REINFORCED CONCRETE PLATES.

By Angus B. MacMillan.*

One of the most recent developments in reinforced concrete construction is the type of flat slab or girderless floor. While this type is in its infancy as yet, examples of it are nevertheless sufficiently numerous to be more or less familiar to all building designers. The absence of beams, the increase of headroom resulting therefrom, the low cost of centering, and the comparatively small amount and simplicity of the steel reinforcement, unite to make this system desirable for many buildings and relatively low in cost.

With its advantages, however, it has some disadvantages, perhaps the most important of which is a lack of detailed analysis of the internal stress occurring in a slab of this kind. It may be mentioned that this analysis is not necessary for safe construction, as the more or less empirical formulæ in use seem to give results sufficiently high, so that enough confidence can certainly be placed in the formulæ to enable the designer to guarantee a test load of twice the designed live load over an entire bay, without harm to the construction and with a very insignificant amount of deflection.

About two years ago, the writer had occasion to design floors of this kind for an office building in Portland, Me. At that time the amount of information concerning the stresses in a concrete plate was very limited, and the writer had some difficulty in finding a satisfactory solution. A study of the buildings of this type gives the impression that Mr. C. A. P. Turner uses in his design a formula equivalent to about $M = WL/48$ to get the bending moment, and that he then solves for an area of steel and distributes the resulting amount uniformly, or nearly so, in the different directions. This seemed so extreme, however,

* Engineer, Aberthaw Construction Company, Boston, Mass.

that no confidence was placed in the result, and various other ways of solving the problem were tried.

For purposes of comparison the writer proposes to give a description of the different methods then used or that have since come to his knowledge, together with the solution by each of a typical floor panel. They are as follows:

1. *Cantilever Method.*—To consider the slab around the head of the column out to the point of inflection as a cantilever supporting a uniform load over its surface and a concentrated load consisting of the rest of the slab hung from its periphery. This will be called the cantilever method.

2. *Turneaure and Maurer.*—To consider the slab around the head of the column out to the point of inflection as a flat circular plate supporting a uniform load over its surface and concentrated load consisting of the rest of the slab with its superimposed load hung from the perimeter of the plate. Diagrams for the analysis of this method are given by Turneaure and Maurer, *Principles of Reinforced Concrete,* pp. 272 and 328.

The first impression of these two methods is that they are almost identical, but the solution and final results are quite different.

3. *Grashof.*—In *Structural Mechanics,* by Greene, p. 255, are given the formulæ for the deflection and bending moments in a plate supported on rows of points forming squares whose side is L. A direct application of this to the typical case will be tried. Two other methods result from a different application of these formulæ: Mensch and MacMillan.

4. *Mensch.*—A more or less incomplete description of this method is given by Mensch in his *Pocket Book,* p. 81, as follows:

> The problem of calculating the stresses in a plate supported at four points was first thoroughly investigated by Grashof in connection with the strength of end plates in steam boilers. He gives the greatest bending moment per lin. ft. in such a plate as $WL^2/26.5$ which formula he derived more by an elimination process than by exact science.
>
> By similar reasoning, we lay down the following rule for the computation of girderless floor construction:
>
> Divide the panels in strips of a width equal to 0.35 L when L is the distance in feet from center to center of support; two strips run diagonally while the others run in the line of the columns. The greatest bending

moment of such a strip we assume to be $WL^2/20$ when the size of the capital is at least 0.23 L.

From this bending moment, we easily obtain the required thickness and reinforcement given in the slab tables on pp. 16 to 20.

In the solution of the typical case the writer has simply copied the slab thickness and amount of steel directly from the tables mentioned, and has not endeavered to perform the actual necessary operations.

5. *Turner.*—Turner recommends and uses a formula that requires considerably less steel than any other method given here. He refers to Grashof's analysis of the stresses in plates given in *Applied Mechanics,* by Gaetano Lanza, and *Theory of the Flexure of a Thin Flat Circular Plate or Ring Loaded Symmetrically About its Centre,* by H. T. Eddy, Engineering Year Book, University of Minnesota, 1899.

In the book recently published on the subject by Mr. Turner, he states that the bending moment $M = WL/50$ where W is the total load on the slab, and L is the span in feet or inches according as the result is desired in foot or inch pounds. Having obtained the bending moment and assumed a depth for the slab, the area of steel is found. This area is divided in the different directions and placed in bands about 7/16 of the span in width.

The method of getting the stress in the radial bars and circular rings is left in doubt. The writer has assumed that they have no function other than to keep the slab steel up near the top of the slab where it belongs when crossing the columns, and to a very limited extent to give a larger bearing for the concrete plate.

What fixes the size of the column heads is not stated to the writer's knowledge.

Turner supports his conclusions with the records of many slabs tested with loads largely in excess of the regular working loads.

6. *MacMillan.*—This method is based on general deductions made from Grashof's analysis of the stresses in a plate supported at rows of points forming squares, whose side is L. Before taking up a typical case, it might be well to indicate what these deductions were. Attention is called to the following formulæ

giving the maximum fiber stress in square plates uniformly loaded, but with different methods of support.

(*a*) Supported on two edges, $f = 3WL^2/4T^2$
(*b*) Fixed on two edges, $f = WL^2/2T^2$
(*c*) Fixed on four edges, $f = WL^2/4T^2$
(*d*) Fixed on four points, $f = WL^2/4.27T^2$

It is interesting to note that a plate fixed at four points is apparently stronger than one fixed on four sides, and is 3.2 times as strong as one supported on two edges.

Now in the first formula the Moment of Resistance can be expressed by $M_r = WBL^2/8$. Therefore, for a plate fixed at four points and the same unit load, the bending moment would be 1/3.2 times this amount, or $WBL^2/25.6$. Using 25 instead of 25.6 for a denominator, the result will be $M_r = WBL^2/25$, a formula that expresses the maximum stress over the head of the column.

Out in the center of the slab, the stress would actually be about one-half of this, or $WBL^2/50$. However, while in continuous slabs supported on beams making the different spans equal the bending moment at the center of the span is $WL^2/24$, the different city building laws only allow the use of $WL^2/10$ or at most $WL^2/12$.

So in this type of floor, the writer sees no good reason for departing from a standard practice and has used the maximum moment and neglected the lesser one. Actually, as all bars are lapped over the columns, there is a large excess of steel at this point, but as the extra strength developed by the lapped bars is to some extent uncertain, it is probably better to get an excess than otherwise.

Having determined the bending moment, it is a simple matter to get the steel area. This steel area is divided up into a number of small bars and distributed in uniform bands in the different directions.

It might be well to say at this point that two other distinct methods were tried without satisfactory results. One depended on considering the amount of load each separate bar should carry, allowing a certain amount of sag in the bar and figuring the stresses in the rod as a catenary. The other was to replace the

straight bars from column to column by an imaginary beam on all sides of the panel (Fig. 1*), and to consider that the bending moment in plane XX was due to the loading indicated by the shaded portions of slab; and that it was equal to $\frac{1}{2}WL/12$ where W = total load on panel, and L = span.

The area of steel to take up this stress was then obtained in the ordinary way except that the diagonal bars were considered to take a stress equal to 16,000 $\sin \phi$ and to be equally effective in resisting stresses in a plane YY. If the beams had really existed, this might have been permissible, but as they did not, it seemed that two other types of loading were possible, one giving the denominator 8 and the other 6 instead of 12, or just double that originally considered.

Of course if the slab was considered continuous, these mo-

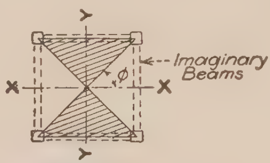


FIG. 1.

ments would in every case be cut down. However, the conditions were not satisfactory, and taking the most unfavorable method of loading, the amount of steel necessary was excessive.

The symbols used in analysing the different cases are as follows:

L = Span.
B = Breadth of panel.
w = Live load.
w_1 = Dead load.
$W = w + w_1$ = Combined load.
M = Bending moment.
R = Reaction at end of strip.
I = Moment of inertia.
ϕ = Angle.
Δ = Deflection.
T = Total thickness of slab.

---

*Acknowledgment is made to the *Engineering Record* for the cuts used in this paper.—ED.

$c \ = \frac{1}{2}T$.

E_s = Modulus of elasticity of steel in tension.

E_c = Modulus of elasticity of concrete in compression.

f_s = Unit fiber stress in steel in tension.

f_c = Unit fiber stress in concrete in compression.

d = Depth from top of slab to center of steel.

jd = Arm from center of compression to center of tension $= 0.86d$.

b = Width of strip considered.

A_s = Area of steel.

V = Fiber stress in concrete in shear.

a = Span in inches in Grashof method.

$\left.\begin{array}{l} r = \text{Radius of column head} \\ r_o = \text{Radius of point inflection} \end{array}\right\}$ Turneaure and Maurer method.

In working out the amount of steel in the different designs, the same unit stress, *i. e.,* 16,000 lbs. per sq. in., has been used in every case, and in Turner's method the slab has also been worked out for the regular working stress of 13,000 lbs. per sq. in. as used by him.

In the methods by Turner, Grashof and MacMillan, the unit stress will be less than that adopted for the Cantilever and Turneaure and Maurer methods, as it was not considered advisable to make the slab less than 8 ins. thick, owing to the difficulty of covering up the steel at the columns in thinner slabs. In getting the deflection in the Grashof method, the deflection was assumed to depend directly on the modulus of elasticity of the concrete, which for stresses up to about 600 lbs. per sq. in. has been taken at 3,000,000, as recommended by Turneaure and Maurer.

For a typical case to be solved by each method the following data will be assumed:

L = 20 ft.

T = 8 ins. unless otherwise noted.

w_1 = 100 lbs. per sq. ft. when $T = 8$ ins.

w = 200 lbs. per sq. ft.

Panel to be square.

1. Cantilever Method.

$W = 300$ lbs. per sq. ft.

Point of inflection of slab for uniform load will be $L/5$ or 4.

Lay out a square with sides 4 ft. from center of column as per Fig. 2.

To get moments at side of column, let uniform load on one side be as indicated by shaded portion.

$$\text{Uniform load} = \left(\frac{(8+1\tfrac{1}{3})\ (4-\tfrac{2}{3})}{2}\right) 300 = 4{,}667 \text{ lbs.}$$

$$\text{Center of gravity of area} = \left(\frac{4-\tfrac{2}{3}}{3} \times \frac{(2\times 8)+1\tfrac{1}{3}}{8+1\tfrac{1}{3}}\right) 12 = 24\tfrac{3}{4} \text{ ins. from edge of}$$

column. Then

$$M_1 = 4667 \times 24\tfrac{3}{4} = 115{,}500 \text{ in. lbs.}$$

We must add to this the moment of the concentrated load hung from the perimeter of the square. This is equal to the

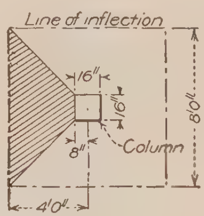


Fig. 2.

load on the entire bay minus the load on the square under consideration divided by the number of sides of the square, or

$$[(20\times 20)-(8\times 8)]\ 300 \div 4 = 25{,}200 \text{ lbs}$$

Lever arm $= (4 - {}^2/_3)$ 12 or 40 ins.

$$M_2 = 25{,}200 \times 40 = 1{,}008{,}000 \text{ in. lbs.}$$

$$M_1 + M_2 = 115{,}500 + 1{,}008{,}000 = 1{,}123{,}500 \text{ in. lbs.}$$

For maximum compression in concrete use 750 lbs. per sq. in., and for maximum tension in steel use 16,000 lbs. per sq. in.

$$E_s/E_c = 15 \quad M = 133bd^2 \text{ and } A_s = 0.0097bd,$$

Taking b, width of column side, at 16 ins., $d = \sqrt{[1{,}123{,}500 \div (133 \times 16]} = 23.6$ ins., say 27 ins. from top of slab to point where column head starts to flare out.

Area of steel at this point is $23.6 \times 16 \times 0.0097 = 3.56$ sq. ins.

It is advisable to obtain the moments and thickness of concrete required to resist the stresses found at several points between the side of the column and the line of inflection of the slab. With these additional points, it is simple to plot a curve for the column head. If these intermediate points are not located, it will be quite safe to carry the column head up at an angle of 45 deg. with the horizontal, as in this instance. Later, when the amount of steel in the slab is obtained, see if it equals the area needed. If not, it will be necessary to add some extra bars over the column head.

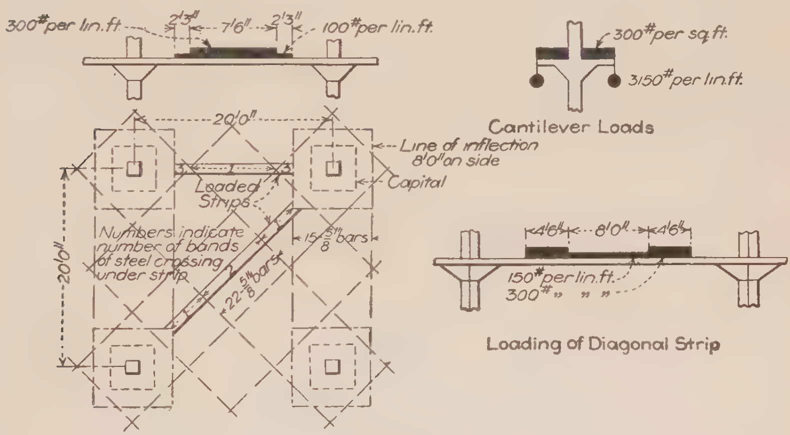


Fig. 3.

Now consider the stresses in the diagonal bands. Take a strip 12 ins. wide between the points of inflection. As the bars cross in the center assume that each band of steel takes one-half the full load where they cross and the entire load where they do not cross (Fig. 3).

The reactions at each end are equal as the load is uniform, and

$$R = [(4\tfrac{1}{2} \times 300 \times 2) + (8 \times 150)] \div 2 = 1{,}050 \text{ lbs.}$$

$$M = (1{,}950 \times 8\tfrac{1}{2}) - (4 \times 150 \times 2) - (4\tfrac{1}{2} \times 300 \times 6\tfrac{1}{4}) = 6{,}938 \text{ ft. lbs.}$$

or 83,256 in. lbs.

$$d = \sqrt{[83{,}256 \div (133 \times 12)]} = 7.21 \text{ ins.}$$

Area of steel $= 7.21 \times 12 \times 0.0097 = 0.8392$ sq. ins.

If 5/8 in. round bars are used, the number of bars required will be 2.73 in a strip 1 ft. wide. Then the spacing of bars in the diagonal bands will equal 12/2.7, or 4.4 ins. on centers. Bands to be made 8 ft. wide, as this fills the area.

Next the stresses in the straight bands between lines of inflection will be obtained. These may be derived in a similar way. Take a strip 12 ins. wide. Over a portion of the length there is but one line of bars, so it may be considered that the whole load is acting here. Near the points of inflection, however, the diagonal bars cross and as there are three layers of bars, we assume that each line takes but one-third of the load at these points.

On this basis, the placing of the metal being symmetrical and the loads uniform, the reactions of the slab at each end are the same and

$$R=[(2\tfrac{1}{4}\times 2\times 100)+(7\tfrac{1}{2}\times 300)]\div 2=1{,}350 \text{ lbs.}$$

$$M=(1350\times 6)-(3\tfrac{3}{4}\times 300\times 1\tfrac{7}{8})-(2\tfrac{1}{4}\times 100\times 4\tfrac{7}{8})=4{,}904 \text{ ft. lbs.}$$
or 58,848 in. lbs.

Using d same as obtained for diagonal strip, 7.21, and jd as 0.86 d,

$A_s = 58{,}848\div(0.86\times 7.21\times 16{,}000)=0.594$ sq. ins., equivalent to 5/8 in. round bars, 6.4 ins. on centers. Bands to be 8 ft. wide as before.

The total area of bars then that cross the column cap is equal to $(.594\times 8\times 2)+(.839\times 8\times 2)=22.9$ sq. ins. As the bars if continuous would resist stresses in opposite sides of column head, take one-half the total area as effective for taking care of the stresses in any one side of the head. This gives 11.45 sq. ins., but from the previous calculations only 3.56 sq. ins. were found necessary, so there is a large excess of reinforcement.

Actually this excess would be still greater as in practice the bars seldom come long enough to be carried continuously over more than one span, especially in the diagonal direction, so a lap is necesary at the columns. The usual method is to schedule the bars long enough to extend 2 ft. beyond the center of the column at each end, making a lap of 4 ft.

2. Turneaure and Maurer.

A careful study of the diagram given in the *Principles of Reinforced Concrete Construction*, pp. 290 and 291, would indicate that as the ratio of r to r_0 decreases, the bending moments in the circular plate decrease. This being the case, it would seem to be an advantage to have a fairly large and very stiff column head. This is readily obtained with the common form of capital used in this type of floor. For instance, assume a circular column 16 ins. diameter. The column head has a flare of about 12 ins. and a depth of about 30 ins. (see Fig. 4), making a total diameter of about 40 ins. at the top. The ratio of depth to flare is 2½ to 1, which should insure ample stiffness.

Take the case used in the preceding examples. It will be necessary to assume the slab somewhat thicker than in the other cases in order to get enough material to resist the apparent bending moments. It might perhaps be admissible to thicken

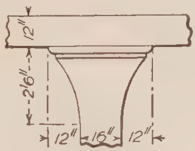


Fig. 4.

the slab gradually near the columns, but *Turneaure and Maurer* do not state this; and further it might complicate the centering to an extent that would not be economical.

Assume the slab 12 ins. thick. Taking concrete at 150 lbs. per cu. ft., the slab weighs 150 lbs. per sq. ft. of area. This added to the live load makes a total of 350 lbs. per sq. ft. With column spacing 20 ft. apart, the diagonals will be 28.28 ft. center to center.

As the point of inflection of a beam fixed at the ends and continuously loaded is about one-fifth of the span length from the end, take the mean for the straight length and diagonal. This will equal approximately $\frac{1}{5}$ $(20 + 28.28) \div 2 = 4.83$, say, about 5 ft.

Having assumed a line of inflection, the area enclosed may be treated as a circular plate having a uniform load over its area and a concentrated load hung from its periphery equal to

the remainder of the panel load. This will equal $[(20 \times 20) - (5 \times 5 \times 3.1416)]\ 3.50 \div (10 \times 3.1416) = 3{,}580$ lbs. per lin. ft.

The ratio of the column head to the diameter of circle assumed is 1 to 3.

Refering to Fig. 5 it is found that the moments caused by the uniform load on circular plate are:

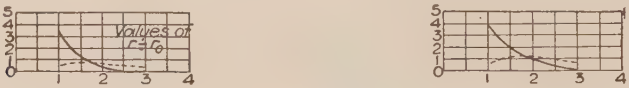
1. Circumferential at column $= 0.4 \times 350 \times 1^2 = 140$ ft. lbs. per ft. width.

2. Radial at column $= 3.5 \times 350 \times 1^2 = 1225$ ft. lbs. per ft. width.

For the concentrated load at the edge the moments are:

3. Circumferential at column $= 0.5 \times 3580 \times 1 = 1790$ ft. lbs. per ft. width.

4. Radial at column $= 4 \times 3580 \times 1 = 14{,}320$ ft. lbs. per ft. width. Adding the moments together, we have 17,475 ft. lbs., or 209,700 in. lbs. per ft. width.



Uniform Load on Slab. Load Concentrated at Periphery.

Dotted Lines=Circumferential Bending Moments

Solid Lines=Radial Bending Moments.

Fig. 5.

Under the same stresses, etc., used in the Cantilever system, $d = \sqrt{[209{,}700 \div (133 \times 12)]} = 11.4$ ins., a depth that does not allow very much room to cover up the reinforcement with the thickness of slab assumed.

Assume that this stress is constant for every linear foot of circumference of cap. The circumference of the capital being equal to 125.66 ins., the area of steel needed around the column head is $125.66 \times 11.4 \times 0.0097 = 13.90$ sq. ins.; but as the bars are continuous, only one-half of this amount, or 6.95 ins., are needed.

These bars are to be arranged in four bands over the head of the column, and the results will probably be near enough if the amount of steel (6.95 sq. ins.) is divided by 4, or 1.74 sq. ins. in band the width of the column head, which is $1.74 \div 40$, or 0.0435 sq. in. per inch width.

Using ⅝ in. bars with an area of 0.3068 sq. in., the spacing will be 7.07 ins. on centers. This spacing had better be continued

out to the point of inflection in each case. Making the bands 10 ft. wide, 17 of ⅝ in. round bars per band are required. It may be that some of these bands can be omitted in the slab between the points of inflection.

Consider a diagonal strip first. Referring to Fig. 6, noting the small figures that indicate the numbers of bars crossing, and assuming that each set of bars takes its proportion of the load, the loads are, scaling the distances

$$[(2\times 2\times 350)\div 3]+(2\times 2\times 350)+[(10\times 350)\div 2]=3{,}616 \text{ lbs.}$$

The reaction at either end is 1,808 lbs.

$M = (1{,}808 \times 9) - (875 \times 2.5) - (700 \times 6) - (233 \times 8) = 8{,}020$ ft. lbs., or 96,240 in. lbs.

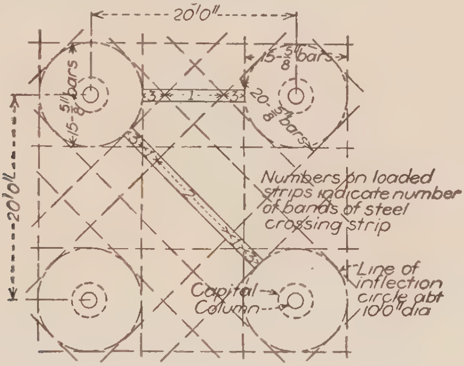


Fig. 6.

Taking depth to center of steel as 10½ ins., it will be found that $96{,}240 \div (0.86 \times 10.5 \times 16{,}000) = 0.667$ sq. ins. are needed, and $(0.3068 \times 12) \div 0.667 = 5.52$ ins. on centers against the 7.07 ins. previously found. It would seem advisable to space the bars somewhat closer in the diagonal directions, say 6 ins. on centers, making 20 bars in a 10 ft. band. This ought to allow of spacing the remaining bars somewhat further apart.

The load in the straight direction on a unit strip equals $\frac{1}{3}(2 \times 2 \times 350) + (6 \times 350) = 2{,}566$ lbs. The reaction at each end equals one-half, or 1,283 lbs.

$M = 1{,}283 \times 5 = (1{,}050 \times 1.5) - (2.33 \times 4) = 3{,}908$ ft. lbs., or 46,896 in. lbs.

$46{,}896 \div (0.86 \times 10.5 \times 16{,}000) = 0.325$ sq. ins. of steel required.

$(0.3068 \times 12) \div 0.325 = 11.35$ ins. on centers for spacing of

⅝ in. round bars. As the stresses in the bars increase toward the edges of the bands, a spacing of about 8 ins. on centers is, perhaps, all that is advisable. This is equal to 15 bars in a band.

3. Grashof.

Grashof's analysis of the stresses in a plate supported at rows of points making squares whose side is a, gives

$$f=\frac{15Wa^2}{64T^2};\quad \text{and } \Delta=\frac{15}{512}\times\frac{Wa^4}{ET^3}$$

As the formulæ are worked out for steel plates for which Poisson's ratio is somewhat different than for concrete, the results obtained may not be accurate but it will be interesting to make the comparison.

W = total load per sq. in. or 2.08 lbs. per sq. in.

a = length of side in inches or 240 ins.

T = effective thickness of slab = 7 ins.

f = $(15\times 2.08\times 240\times 240)\div(64\times 7\times 7)=573$ lbs. per sq. in., maximum fiber stress.

However, this fiber stress is based on the moment of inertia of a homogeneous material like steel whose center of gravity is ½T from the bottom. As this does not hold for concrete, the bending moment per unit width, may be determined by the formula.

$$M=\frac{fI}{d}=\frac{573\times 7\times 7\times 7}{3.5}=56{,}162 \text{ in. lbs. per ft. width.}$$

A somewhat lower stress on the concrete than in the previous example will be used. In this instance let f_c = 650 lbs. per sq. in.

Using $d=M/108b$ and $A_s=0.0077bd$, gives $d=56{,}162\div(108\times 12)=6.59$ ins., which is fairly near the 7 ins. assumed for d, and

$$A_s=0.0077\times 6.59\times 12=0.608 \text{ sq. ins. per ft. width.}$$

From a comparison with the position and magnitude of stresses in continuous beams, it will be safe to consider the maximum stress in the present case as the negative stress at the column in the direction of the diagonals, and that the positive

stress half-way between the columns diagonally is but one-half this amount or less.

Also assume that the concrete plate will get the full stress indicated at the column and must be able to resist this stress from any direction, so that instead of one set of reinforcing bars, there must be at least two sets crossing at right angles to each other. Actually in this system there are four sets which will be lettered *a, b, c,* and *d* crossing as shown in Fig. 7. It will now be apparent that any stress tending to rupture the slab in the vertical plane, will be resisted by bars *b* directly up to their area bA_s, and that bars *c* and *d* will assist in the ratio of $A_s \cos \phi$. Then to resist the stress in plane *XX*, there is

$$f_s(bA_s + cA_s \cos \phi + dA_s \cos \phi)$$

$$\phi = 45 \text{ deg., so } \cos \phi = 0.707.$$

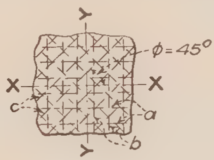


FIG. 7.

Now as the component forces of bars *c* and *d* for resisting stresses in the vertical plane *YY*, are the same as for *XX*, we may write $f_s\ (aA_s + cA_s \cos \phi + dA_o \cos \phi)$ for the area of steel needed to resist stresses in *YY*.

But it was previously found that 0.608 sq. ins. of steel was needed to resist *M* in any one plane, say *XX* ,therefore the same amount will be needed for the equal stress in *YY*, so

$$f_s(aA_s + bA_s + 2cA_s \cos \phi + 2dA_s \cos \phi) = f_s(2 \times 0.608) \text{ for an area 1 ft. square.}$$

As f_s is constant and bands *a, b, c,* and *d* are equal,

$$A_s = (2 \times 0.608) \div [2 + (4 \times 0.707)] = 0.252 \text{ sq. in. per ft.}$$

If the area of a ⅜ in. bar = 0.1104 sq. in., the spacing of the bars equals 5.25 ins. center to center.

Now if bands are made the width Mr. Turner recommends, *i. e.*, 7/161, the number of bars in a band will be $(20 \times 12 \times 7) \div (16 \times 5.25)$, or 20 of ⅜ in. round bars per band.

If it is assumed that the stresses in the center of the slab are approximately but one-half of those at the column, but one-half the amount of steel will be needed. There actually is 0.252 sq. in. and 0.608/2, or 0.304 sq. in. are needed; but as the bars are crossing each other in the center of the span and as tests of expanded metal seem to prove that the concrete develops higher resisting powers when reinforced with metal in the form of a mesh, this may, perhaps, stand as it is.

The deflection by this method, using $E_c = 3{,}000{,}000$ is $(15 \div 512)\ [(2.08 \times 240^4) \div (3{,}000{,}000 \times 7^3)]$, or 0.196 in., a little more than 3/16 in.

The size of the column head, of course, will serve to modify, more or less, the results obtained by any method, and the writer can think of no better way than to make the diameter of the cap of such a size that the vertical shear at its perimeter will not exceed 80 lbs. per sq. in.

4. Mench.

It will not be attempted to analyze this method and the results given in the tables on p. 56, of Mr. Mensch's book are copied without demonstration.

Area of steel in strip per ft. of width, 0.75 sq. in.

Width of strip, 7 ft.

Size of column capital, 4 ft. 6 ins.

Weight of steel per sq. ft., 5.3 lbs.

Total weight in panel $= 20 \times 20 \times 5.3 = 2{,}120$ lbs.

The percentage of steel per ft. width = 0.89 of 1 per cent.

Mensch states that the rods running in the direction of the columns should extend into the adjoining panel $0.12L$, and those running diagonally should extend $0.16L$ beyond the column center.

5. Turner.

Let $M = WL/50$ and $f_s = 13{,}000$ lbs. per sq. in.

All other quantities to have the same index as in previous cases.

1. $W = (200 + 100) \times 20^2 = 120{,}000$ lbs.
2. $M = (120{,}000 \times 20 \times 12) \div 50 = 576{,}000$ in. lbs.
3. $A_s = 576{,}000\ (0.86 \times 7 \times 13{,}000) = 7.38$ sq. ins
4. The area of a ⅜ in. round bar = 0.1106. Therefore

$7.38 \div 0.1106$, or 66.7 of ⅜ in. round bars, say 68, will be required.

5. Number of bars in band = 68/4, or 17.

If f_s = 16,000 lbs., then $A_s = (576{,}000) \div (0.86 \times 7 \times 16{,}000)$ or 6 sq. ins. nearly. This gives $6 \div 0.1106$ or 54.2 bars of ⅜ in. diameter. Therefore, $54.2 \div 4$ or 13.55 bars, say 15 bars in each band are required.

6. Width of band $y = (7 \times 20) \div 16$ or 8ft. 9 ins.

Mr. Turner does not state what rule he uses to obtain the size of his column capitals.

The deflection of the slab by Turner's method

$$\Delta = (1/7000)\,[(60 \times 20^3) \div (4 \times 17 \times 0.1106 \times 7^2)] = 0.19, \text{ about } 3/16 \text{ ins}$$

6. MACMILLAN.

L and B equal length and breadth of panel respectively, in feet. When panel is square, $L = B$; when rectangular, L is greater than B and must be used in getting the bending moment.

y = *width of bands* of steel = $7/16\ L$ approximately.

V = 80 lbs. per sq. in.

Jd will vary according to E_s/E_c and to the percentage of steel used, but 0.86 is a good average. It will not be found advisable to make d less than 7 ins. regardless of load, on account of the difficulty found in embedding the bars in concrete.

Using the values for typical case,

$W = (w + w_1)\ LB = (200 + 100) \times 20 \times 20 = 120{,}000$ lbs.

$M = 12\ WL/25 = (12 \times 120{,}000 \times 20)/25 = 1{,}152{,}000$ in. lbs.

$A_s = M/\ jd\ f_s = 1{,}152{,}000 \div (0.86 \times 7 \times 16{,}000) = 11.95$ sq. in.

The area of a ½ in. round bar = 0.196 sq. in., and therefore $11.95 \div 0.196$ or 61 bars will be required. Number of bars in band = $61 \div 4$ or 15.25, say 16 each way diagonally and 15 each way straight.

Diameter of column cap = $W/\pi Tv = 120{,}000 \div (3.1416 \times 8 \times 80) = 59.6$ ins.

Width of band $y = 7\ L \div 16$ or 8 ft. 9 ins.

It will be desirable to get the depth of cap at the junction with column by solving for depth at that point, having shear and diameter of column fixed.

The radial bars and rings have generally have been made of 1 in. round rods, the rings being lapped at the ends about 2

ft. and U-bolted togther, or else welded. These rings are placed so that they bring the slab bars up near the top of the slab at the columns.

In general, f_s = 16,000 lbs. per sq. in. has been used for stress in tension with plain round bars. The percentage of steel has been kept below 0.5 per cent. for a single layer of bar-

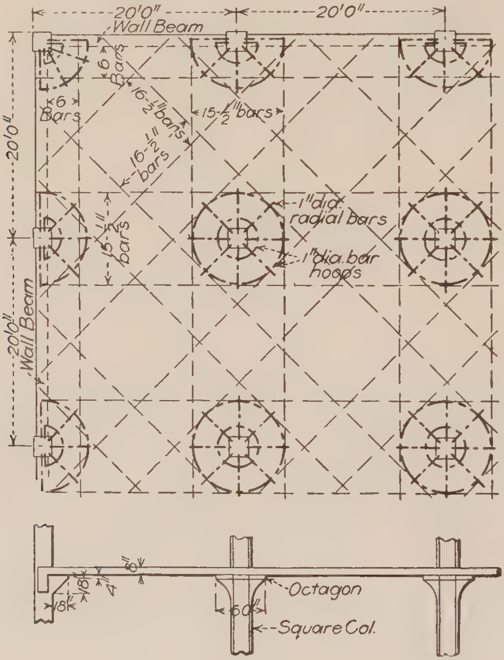


Fig. 8.

The wall beams are designed to carry ¼ of the panel loads and, if necessary, the columns are calculated for stresses caused by eccentric loading. The wall panels are made the same as the interior panels, and where holes of a reasonable size occur, they have been made in the slab without hesitation.

The deflections occurring have never been calculated but the tests made indicate that they are quite insignificant. This method has been used by the writer in connection with seven buildings designed by various engineers and architects. A typical design is shown in Fig. 8.

It would seem that if the writer's interpretation of Turneaure and Maurer's diagrams and descriptions is correct, the results are extremely heavy, much more so than any existing work would lead one to believe necessary.

Only recently in fact the writer agreed to test a slab with a live load of 450 lbs. per sq. ft. This slab was 9 ins. thick and the reinforcement consisted of ½ in. round bars 7 ins. on centers. Columns were spaced 20 ft. on centers. The slab was cast 8 ins. thick, and later 1 in. of finish was put on. A box without a bottom whose sides were long enough to span from column center to center, and 5 ft. high, was built resting on the concrete slab and enclosing one bay. In the center of this bay a target was attached to the under side of the slab so that readings for deflections might be taken. The box was then filled with sand. At a load of 200 lbs. per sq. ft. no deflection of the slab could be measured. At this point, as the slab was cast in cold weather and was quite green, it was decided to put some shores under the panel and then continue the loading to the required amount. Later, when the concrete had a little more chance to season, that is 88 days after casting, the shores were taken out and the whole load was allowed to come on the slab.

The deflection under the total load was 5/64 ins. This is about 1/3000 of the span with over twice the figured live load superimposed. This certainly does not seem to indicate that as thick a slab or as much steel as this method seems to demand was necessary.

Table I gives the weights of steel required by the different methods and may be of interest.

A few points worth mention are noticeable in Table I.

First, the similarity of methods 1, 2 and 4 in regard to amount of steel. This holds true of methods 3 and 5*b* also.

Second, the marked difference in thickness of slab required by the second method.

Third, the remarkable closeness in deflections obtained in methods 3 and 5*b*.

Regarding the merits or demerits of the different methods, the writer can say little except that the floors designed by his method have been low in cost, have shown remarkable powers

of resisting abuse, have stood tests of twice the live load over an entire bay, not only without signs of failure but with such trivial deflection that one is led to believe that the constituent materials are far from being stressed inordinately.

It may be well to call attention to one other point that may give trouble to the designer of this system, that is, the ratio of length to breadth of panel. It will be apparent that as the greatest length is used in getting the bending moment, the depth of the slab and the amount of steel increase rapidly with the increase of length, and the variation of stresses will become very uncertain. In consequence it would seem that nearly square

Table I.—Summary of Steel Required.

Method.	Thickness of slab. Inches.	Fibre stress. Lbs. per sq. in. in steel.	Lbs. steel in panel.	Deflection. Inches.
1. Cantilever	8	16,000	2,189	....
2. Turneaure and Maurer	12	16,000	1,931	....
3. Grashof	8	16,000	784	.195
4. Mensch	8	16,000	2,120	....
5 Turner (a)	8	16,000	549	....
(b)	8	13.000	718	.19
6. MacMillan	8	16,000	1,084	....
Average (not including 5b)	8.66	16,000	1,463	....

slabs were desirable and that an increase of length over breadth of more than 25 per cent. is perhaps not economical practice.

The most economical spans would seem to be from 16 to 24 ft. For shorter spans the cost of columns runs up pretty fast.

A heavy floor load seems to show greater relative economy than a light one. Where speed of erection is a desideratum, the flat floor slab with its absence of beams is far ahead of any other method. The wood forms can be built into panels and laid in place by rough form builders, carpenters being used only for shoring and leveling; and there being no beams to be taken care of, little if any of the sawing and fitting necessary when they are part of the design has to be done. The bent steel is reduced to a minimum, being confined almost entirely to the

columns, distributing rings and wall beams. The bars themselves, while fairly long, are generally quite small in section and easily handled, and will readily sag of their own weight to the required position at the center of the span without having to be held down.

The joints where the day's concreting is stopped are infrequent, and the danger of temperature or shrinkage cracks with such a network of steel is minimized.

DISCUSSION.

Mr. Mensch.

MR. L. J. MENSCH.—Mr. Grashof's formula covers panels which are uniformly loaded throughout. It is certainly rational to assume, that the same ratio of bending moments between the ideal condition of a continuous beam, uniformly loaded, and beams, as designed and loaded in an every-day building, should also hold good for the girderless floor. Now this ratio is as $WL^2/24 \div WL^2/10$ or $1:2.4$. Even if the formula $WL^2/48$, which some claim, may be deduced from Grashof's writings, would be correct for a great number of uniformly loaded panels, this would not allow us to figure with a smaller moment than $WL^2/20$. There is no question that the case might happen that each alternate panel is loaded, then of course the formula $WL^2/48$ is not correct, in fact the greatest bending moment might not be in the center, but over the column heads, and this is the reason why I propose in my book to figure the moments in girderless floors by the formula $WL^2/20$. I wish to add that these slabs are relatively so thin in comparison to the columns that the latter are very highly strained in bending through the loading of the slabs. In my opinion the only reason why those buildings show such good behavior is because the columns are evidently large and help the floor slabs considerably. But if you would load the same slabs with three or four times the load for which they are figured, I am sure you would find considerably more trouble than is reported. I understand there are a number of buildings where circular cracks around the columns have developed. Very often these cracks are not visible if the floor slabs are not cement finish, because the dirt fills them up, but you find them easily when the floor slabs are cement finish. There is no question but that the high test loads which are reported to-day can be carried without any reinforcement whatsoever, because the whole floor rests on the girders and takes up the thrust. I am quite certain omitting every pound of metal from that slab, as soon as it can stand the shear, it will carry the same test load with the same deflection. I do not consider this con-

struction safe with a factor of safety of 4, if a lower bending moment than what I propose is used. I think $WL^2/20$, which I propose, gives a factor of safety of 4. If you go lower you only have a factor of safety of so much less. **Mr. Mensch.**

MR. FRIDSTEIN.—Supplementing Mr. Mensch's remarks on the action of floors, I have been working for the past six months with a contractor who has erected eleven or twelve buildings of the flat slab type. The practice of this contractor has been to strip the floor and take out all the shoring before putting on the top finish. The top finish was put on before the forms were taken out in three cases, twice on account of the architects and once because the engineer wanted it that way. In all three of these cases the top surface of the floor invariably cracked, radially and in a circle parallel to the column. In one case this crack seems to extend clear through the slab, and you can pour water through the cracks. Now this contractor claims that there is a deflection, although he has never measured it. He claims that there is a deflection in the slab as soon as the forms are taken out, and that if the forms are taken out before the top finish is put on, the floor will always show cracks after stripping the forms. **Mr. Fridstein.**

MR. MENSCH.—I do not think that the cracks are caused because the forms are taken out too early, because the deflection is so small, even in the finished building. **Mr. Mensch.**

MR. LOUIS F. BRAYTON* (by letter).—Without question, one of the most useful as well as one of the least understood types of construction is the reinforced concrete flat slab. The fact that Mr. MacMillan's summary indicates a variation of about 400 per cent. between the lowest and highest amounts of reinforcement used under the various methods of computation where the same problem is under consideration, fully indicates that there is at least no accepted method of computation in general use. Without going into the details of the various methods it may be generally stated that nearly all of them use as a basis the idea that a slab deflects in the form of a warped surface. It might be said that it is assumed the slab droops around each column in an umbrella form, the curve being reversed as it approaches the center of the span until it meets the corresponding curve from the next column. **Mr. Brayton.**

* Superintendent, Stone and Webster Corporation, Portland, Ore.

Mr. Brayton. In the writer's mind, where the flat slab is designed on columns equi-distant in each direction, that is, the panels are square, and where the load is absolutely uniform all over the entire floor there is probably no question about the slab deflecting into the form of a warped surface, as described above. However, when a panel is oblong, and the thickness of the slab uniform, there will probably be a greater stiffness in the direction of the shorter span and the deflection will not necessarily take the form of a warped surface. The greater deflection in the slab may take place along a line perpendicular to the center of the long span. This argument is presented to put the problem in another light. It is not the idea to say that it is impossible for the oblong flat slab to assume the warped surface, but it is intended to say it may be possible that it may not under all conditions take the form of the warped surface.

Another point of view which must be considered is that if we grant that the flat slab under a uniform load will assume the form of a warped surface when it deflects, are we at liberty to take this fully into account in making our calculations? Take for example a slab supported upon four sides by girders. In this case there can be absolutely no question but what the slab under a load does assume a warped surface, for the deflection along both spans is the same, and, since the girders are considered practically non-deflecting and the center of the slab does deflect, there can be no other condition but that the slab is warped and dished under the load. Building departments and engineers throughout the country do not give slabs supported upon four sides very much credit for this warping. Probably, the most usual concession given by a building department is that the load may be considered carried in the direction of the two spans, that is, where the panel is square one-half of the load is carried each way. After determining the amount of steel required under these conditions, the amount actually required may be considered as equal to three-quarters of that figured, the bars being gradually increased in spacing toward the end of the span. This, it must be remembered, is a concession made only where there is absolutely no question that the only form that the slab can assume under deflection is that of a warped surface. In a flat slab where there are no beams along the center lines of the

columns, as noted above, it is not certain by any means that the slab under a load will deflect in the form of a warped surface, and under these conditions the attitude of engineers and building departments certainly ought not to be more liberal than where a slab deflects as it would when supported by girders on four sides. **Mr. Brayton.**

Another condition which probably in a large number of slabs under test has come into effect, is the fact that the flaring caps in the columns are so perfectly a part of the slab and column at the same time, that a large part of the strength of the slab is due to the fact that it is fixed about the columns, and, that through a moment of resistance in the columns the slab is materially strengthened. In other words, an eccentricity is created in the column by means of its continuity with the slab. A proper engineering design would not contemplate this eccentricity in the columns, unless the columns were designed to take care of it, which in the interest of economy can not be done.

It seems to the writer that under the conditions discussed a fair solution of the problem would consider the entire dead plus live load as being carried in the direction of the long span where the length is greater than one and one-half times the breadth, the bending moment, however, being calculated on the most liberal basis consistent with good engineering. When a panel is square, it ought to be fair to go to the extreme limit and consider that the bending moment at the center of the span is equal to $WL/24$, W being the entire dead plus live load. This is equivalent to considering half the load is carried in each direction, but using the more conservative factor 1/12 instead of 1/24, thus giving credit for deflection in two directions.

When a panel is oblong to the extent of one and one-half times its width the whole load should certainly be carried on the long span using a formula for bending moment giving M equal to not less than $WL/12$ at the center and $WL/24$ at the support.

For panels only slightly oblong it is a question whether the proportion of load carried by the long span can be properly considered as equal to the proportion usually assumed in slabs supported on four sides.

The illustrations represent a flat slab where the columns are spaced 20 ft. on centers each way and where the design is made

Mr. Brayton. for a live load of 200 lbs. per sq. ft. The plan, Fig. 1*, shows the arrangement of the bars, their number in each band and the widths of the bands. The moment diagram, Fig. 2, is taken along the center line of columns *AB*. The section, Fig. 3, is taken along the same line indicating the arrangement of reinforcement constituting the band *AB*, but not the bars in the

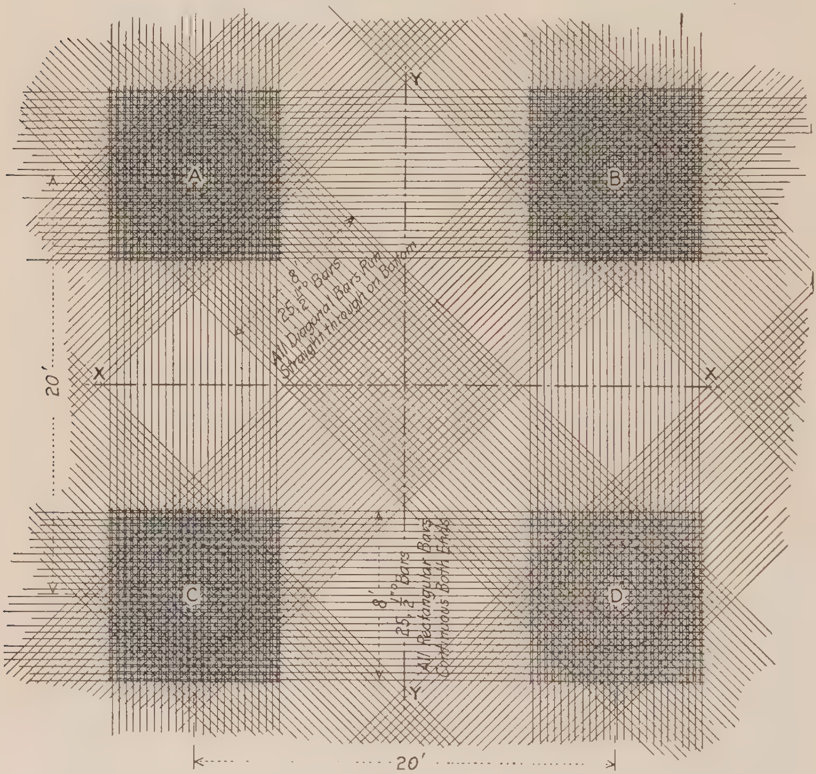


FIG. 1.—PLAN SHOWING ARRANGEMENT OF BARS.

diagonal bands. In Fig. 2 the parabolic moment diagram indicates the location of the moment when it is considered that one-half of the load is carried in the direction of each span, the bending moment M being considered as equal to $(1/12)\ (WL/2)$ at the center of the span and $(1/24)\ (WL/2)$ at the point of support. This negative moment of $(1/24)\ (WL/2$ at the support,

*Acknowledgment for the cuts used in this discussion is made to the *Engineering News*.—ED.

however, is based on a strip of the same width as that considered at the center of the span and since the width of the column cap resisting negative moment is only about 40 per cent. the width of the panel, the total negative resistance which must be provided per foot of width of cap must be at least two and one-half times this amount. Mr. Brayton.

In order to design a slab and reinforcement to resist these

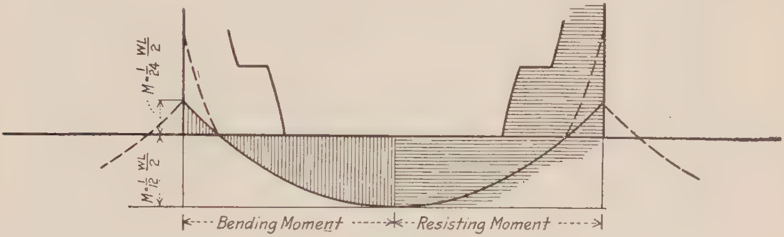


FIG. 2.—MOMENT DIAGRAM.

bending moments, a strip one foot in width running from *A* to *B* is assumed having a span of 20 ft., and a live plus dead load of 307 lbs. per sq. ft. Using a stress in the steel of 16,000 lbs. per sq. in., and an extreme fiber stress in the concrete of 600 lbs. per sq. in., it will be found that a net depth of 7½ ins. at the center of span is necessary. The steel required at the center of the span must be doubled over the column, and that since the entire

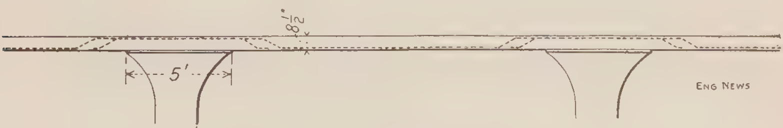


FIG. 3.—DIAGRAM SHOWING REINFORCEMENT ALONG AB.

strength of the concrete at 600 lbs. per sq. in. has been developed at the center of the span the compressive resistance must be increased enough to take care of the negative moment of resistance at the point of support. The cross section through the slab along the line *AB* indicates how this steel is bent to the exact form and how the overlapping ends coming from each side of the column give over the column double the amount of steel that is supplied in the center of the span. The moment diagram shows

Mr. Brayton. on the right the positive moment of resistance at the center of the span and the negative moment of resistance toward the point of support as it is created by the doubling of the reinforcement at the top of the slab, and the increasing of the compressive resistance of the slab due to the influence of the flaring column cap, and the diagonal reinforcement of the slab. It will be seen by the resistance diagram on the right that the shaded area amply covers the moment diagram.

Having determined the amount of metal required per foot of width in the band *AB*, the next step is to determine the width of this band. As it is considered that the slab might fail by deflecting along the line *YY*, it will be seen that the concrete will be put into compression and the metal into tension along lines perpendicular to *YY* no matter whether the point considered is within the band *AB* or in one of the bands *AD* or *CB*. The fact that the metal through the center of the panel is placed diagonally does not necessarily mean that the lines of stress in the concrete must be diagonal, for since the line *YY* may be along the line of maximum deflection, the lines of stress will be perpendicular to *YY*. So far as concrete compressive stresses are concerned this is simple, and the metal is simply necessary to resolve the tensile stress in each bar into its components, parallel and at right angles to *YY*. The sum of the components of the two bands *AD* and *CB* perpendicular to *YY* must be the tensile resistance required for that portion of the panel not covered by bands *AB* and *CD*. In a square panel it will be seen that 0.707 of the stress in any bar running diagonally will be equal to its component perpendicular to the line *YY*. Since we have two diagonal systems crossing this portion of the panel the total stress perpendicular to the line *YY* will be equal to 1.414 times the tensile strength of either system. Consequently, if we adjust the bands *AB* and *CD* to such a width that the strip between them must be equal to 1.414 times the width of the band *AB* and place the same amount of metal in all four bands, we have supplied the proper amount of metal to resist bending along the line *YY*.

In the system illustrated it is customary to have the bars in the rectangular bands bent and continuous at both ends, while the diagonal bars are straight and run through on the bottom.

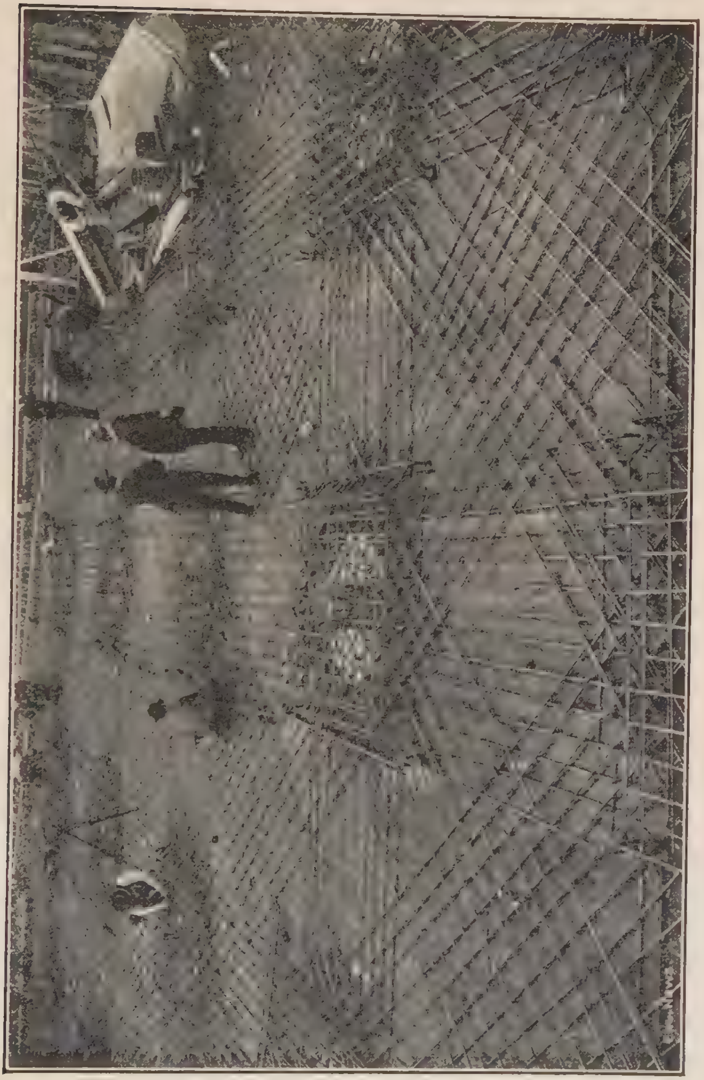


FIG. 4.—LAYOUT OF REINFORCEMENT.

Mr. Brayton. The rectangular continuous bars are erected first, the diagonal bars being afterwards threaded under the negative bars over the column. A study of this system will show that every bar is either carried directly or indirectly over the column cap.

Fig. 4 shows the reinforcement used, in which the shear is largely taken care of in the reinforcement.

With the arrangement given it will be found that the double continuous rectangular reinforcement in a square panel will almost exactly equal in length the diagonal distance between column centers, consequently whether the diagonal reinforcement be carried through the column continuously, or whether it be spliced with broken joints the amount of reinforcement required for the entire panel will be equal to four times that required for one band having a length equal to the diagonal distance between centers of columns.

Following is the solution of the problem already stated considering the half load carried in each direction and the bending moment at the center of the span equal to $(1/12)\ (WL/2)$.

It may be noted that when a square slab is designed on a basis as set forth above, L being the distance from center to center of column and W being the total dead plus live load per sq. ft., the weight of metal required in the slab per sq. ft. may be closely determined by the following formula:

$$0.135\, L \sqrt{W} = \text{weight of metal per sq. ft.}$$

Applying this to the above problem we have

$$0.135 \times 20 \times \sqrt{307} = 4.73 \text{ lbs. per sq. ft.}$$

It is interesting to compare the above design with various designs given by Mr. MacMillan, whose results with the above result added are shown in Table I.

The writer believes that the system shown, particularly in its detail, has advantages which are apparent to most engineers in that the shear or diagonal tension in the slab is very materially assisted by the arrangement of the reinforcement, and the bars because of being bent mechanically are positively located so that they take care of the negative bending moment.

The economical bending of the bars is done by means of a right and left double bar bender at a very low cost, which puts four bends in a bar at once, and ensures the bending of the bar

to exact detail. Springing the bars into place, or allowing them to sag under their own weight, leaves a great deal to the contractor and causes a lack of confidence by the engineer that the reinforcement will be placed exactly as intended. Circular cracks running around the top of a column in a slab are utterly impossible when the steel is as exactly placed as shown. The fact also that only two systems of reinforcement occur in the top surface means that the effectual depth is not materially decreased as where it is necessary to carry all four systems to the top surface. **Mr. Brayton.**

MR. EMILE G. PERROT (by letter).—The reinforced concrete engineers owe a debt of gratitude to Mr. MacMillan for his very able and exhaustive research into the method of computing what **Mr. Perrot.**

TABLE I.—AMOUNT OF REINFORCEMENT REQUIRED PER PANEL ACCORDING TO VARIOUS DESIGNS.

Method.	Thickness of Slab.	Stress in Steel. Lbs. per Square Inch.	Steel in Panel. Lbs.
1. Cantilever	8 in.	16,000	2,189
2. Turneaure and Maurer	12 in.	16,000	1,931
3. Grashof	8 in.	16,000	784
4. Mensch	8 in.	16,000	2,120
5. Turner (*a*)	8 in.	16,000	549
(*b*)	8 in.	13,000	718
6. McMillan	8 in.	16,000	1,084
7. Brayton	8½ in.	16,000	1,900

he terms "Girderless Floors." The writer can sympathize with his endeavors to arrive at a safe and sane formula for this system of construction.

This discussion of the six methods of solution of a typical floor panel ably presents the different methods by which floors of this character are designed. In Table I, p. 266, giving the weights of metal required by the different methods one finds a vast discrepancy in the amount of metal required. Taking Turner's formula (A) the amount of steel per panel is only 549 lbs., while that under the cantilever method (No. 1) requires 2,980 lbs., or four times as much steel. The writer would call attention to the fact that any system whereby the calculations can vary 400 per cent., is far from being out of the experimental stage. While tests on various floors constructed by different persons show their wonderful car-

Mr. Perrot. rying capacity, the results obtained are no more remarkable than what has been obtained in slab and beam construction.

Mr. MacMillan stated that in one floor which he tested the deflection was only 5/64 of an inch on a 20-ft. span, with a load of over twice the figured live load. The writer has tested beam and slab floors with a span of 27 ft. with a load of twice the calculated live load in which there was no appreciable deflection, it being so slight that it could not be registered. Further, in testing a floor with twice the live load on a 54-ft. span of the T beam construction, the greatest deflection obtainable was only ¼ in. in the middle. If we consider these deflections as indicating the strength of the floors, it would be evident that the factor of safety on beam and girder floors is greater than on girderless floors.

While there are advantages in omitting the beams from the ceilings of buildings where the law limits the height to a specified number of feet, making it possible to introduce another story, the girderless floor system is an advantage, but for general work where the building is not being designed to suit a construction, but the plant is being designed to suit the convenience of those who are to occupy it, and the arrangement of the machinery, a greater variety of post spacing is permissible when beams and girders are used.

When the question of the distribution of light enters into the building, a very good system of constructing the floors is to run deep girders across the building parallel to the source of light, making the length of the spans equal to twice the distance between the girders, and introducing shallow cross beams midway of the bay and at the edges forming square panels, the slab being reinforced in two directions. The writer has used such a system, and found that one gets the advantage of spacing the columns far apart, which is usually of considerable importance in a manufacturing building, and permits of the high windows running up close to the bottom of the floor slab, the top of the lintel being set above the floor, and the absence of beams near the windows permits of the ceiling acting as a reflecting surface. The thickness of the slab in such a construction is much less than what it would be for a girderless floor, while the large girders add to the rigidity of the building, by forming stiffening ribs from one side to another.

With such a system it is possible to more accurately determine the stresses in the various parts of the construction than a system such as girderless floors. **Mr. Perrot.**

There seems to be no good reason why a construction that has been tested in full-sized members to destruction should not be given preference over one which has not been tested to destruction. Until such a test is made the methods of figuring girderless floors are not much better than conjectures.

MR. C. A. P. TURNER (by letter).—Engineering, it is supposed, should be a science. We design members of structures based on our experimental knowledge of the strength of the materials used. The nearer these tests come to tests of working construction the more exact becomes our design. **Mr. Turner.**

The general criticism of the theories presented by Mr. MacMillan lies in the fact that as presented they appear all to be based on assumptions and not on exact experimental data. For example: Mr. MacMillan gives the writer's formula, but he does not undertake to explain the derivation. We know from the elementary principles of mechanics that the internal moment of resistance must equal the external moment of the load. This gives us a definite relation between the external forces and the internal resistance at the weakest point of the slab. This weakest point can readily be determined by experiment. The external moment must equal some coefficient times the total load W, times the span in feet. This coefficient is unknown and must be determined. This can be done by loading the floor until the reinforcement commences to yield.

Using a grade of steel of known quality in which we know by test the stress under which the steel commences to show its first permanent stretch, we may load the panel to this point and then determine the coefficient to be applied in the equation giving the relative external moment. Thus we determine experimentally by two different experiments the strain on the steel and the coefficient involved in the external moment. We make no assumption whatever, but have absolute results in the simplest possible manner and with no doubt or question as to what these results will be in all cases in which similar arrangement of the reinforcement is used.

Mr. Turner. The inherent difficulty with the theory proposed by Mr. MacMillan is that where reinforcement in two or more directions is used it is impossible to separate the slab into strips and treat the strips as independent beams along the line of the common theory of one-way reinforcement. Any who have made tests of criss-cross reinforcement will appreciate the fact that ordinary theory applied to such reinforcement is in error more than one hundred per cent. Hence, we should not guess or use approximate methods in designing any structure of this character, but should determine scientifically from actual tests the strength of the construction. Such simple methods do not appeal to those who like a complicated mathematical theory, but they do appeal to the practical constructor who must know definitely the strength of the construction which he is forced to guarantee.

A METHOD FOR LONG SPAN, LIGHT FLOOR, REINFORCED CONCRETE CONSTRUCTION, WITH COMPARATIVE COST.

By Emile G. Perrot.*

While there has been no doubt of the economy and practicability of reinforced concrete for massive construction and where heavy loads are carried, the advisability of its use for light floor loads, especially if the spans are long, has been questioned even by those who favor its use in other instances. The dead weight of the material itself has often operated against its use, especially where the carrying capacity of the soil required the unit pressure to be kept to the minimum, or from other like causes.

We all agree that clear spans of forty or fifty feet in buildings are not usual and are generally avoided on account of their increased cost; hence a description of such span, with its cost as compared with steel girder construction for the same span, is of interest. While the author does not wish to take any credit for originality in the design of this floor, as the same general scheme has been used many times before for shorter spans, it is because of the unusual length of the span that its details become an important factor in the design.

The spans in question form the floors over the swimming pool and gymnasium of the Philadelphia Turngemeinde Club House, and are 53 ft. 1⅞ ins. clear span. There are two floors, (Fig.† 1) with these spans, of an area of about 4,700 sq. ft. each, having five girders on the first floor and six on the second floor, spaced 13 ft. 9 ins. centers. Those of the first floor are only 36 ins. deep below the joist, on account of

* Ballinger and Perrot, Architects, Philadelphia, Pa.

† Acknowledgment for the cuts used in this paper is made as follows: *Engineering Record*, Figs. 1 and 3; *Engineering News*, Fig. 2; *Concrete Engineering*, Fig. 4.—Ed.

head room. The top portion or T head is 5 ft. 4 ins. wide and 14 ins. thick. These girders are reinforced with twenty-one 1⅛ in. square twisted bars, bent as shown in Fig. 2. The stirrups are 1 × ⅛ in, flat iron, bent and spaced as shown. Great care was taken to place the bars accurately in position, and the bottom bars were supported in the bottom of the molds on cast cement chairs, while the spacing of the bars and stirrups was maintained by iron rods and the wiring of one bar to the other. Fig. 3 shows details of the forms.

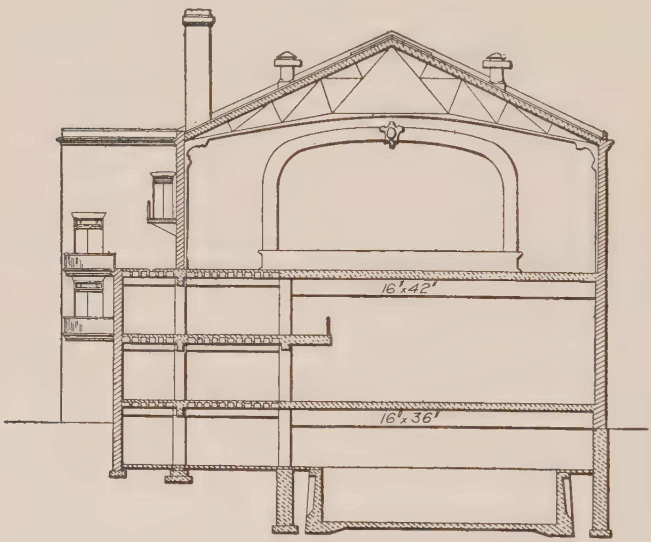


FIG. I.—CROSS SECTION THROUGH AUDITORIUM AND GYMNASIUM.

The floor panels between the girders consist of 5 × 12 in. concrete joists, with a 2 in. reinforced concrete slab over same, and 12 × 12 in. plaster block centers between each joist, thus making a flat ceiling between girders, Fig. 4. The joists are reinforced with one $^{11}/_{16}$ in. square twisted bar, and eight ¼ in. stirrups. In the top of every third joist were placed two ¾ in. square twisted bars over the girders to act as a tie. These rods were only 5 ft. long but two were used in each case, lapped in the center so as to project beyond the T head into the joists.

The slab is reinforced with ¼ in. rods run in both directions, 12 ins. on centers or thereabouts.

The girders supporting the auditorium floor, on account of

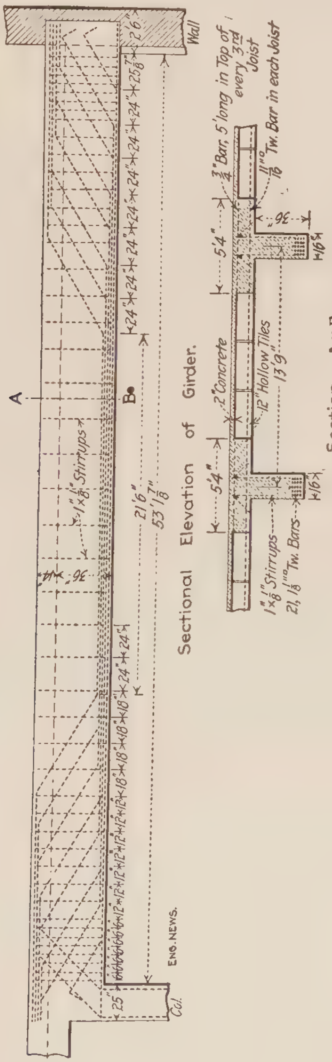


FIG. 2.—DETAILS OF GIRDER.

the higher ceiling, are 42 ins. deep, with T head, 4 ft. 9 ins. wide. The reinforcement in the bottom consists of eighteen 1⅛ in square twisted bars, bent the same as shown for first floor.

Each floor is designed for a live load of 120 lbs. per sq. ft., as the top floor is an auditorium and the lower floor being a gymnasium.

There seemed to be some doubt among the members of the Building Committee as to the advisability of constructing such a long span of reinforced concrete, and one of the committee went so far as to offer to increase his subscription to the building fund by a very large amount, in order to pay for steel girders, but the amount offered was insufficient to pay the extra cost, so the girders were built of reinforced concrete as originally designed. In order to obtain the actual difference in cost, the girders were

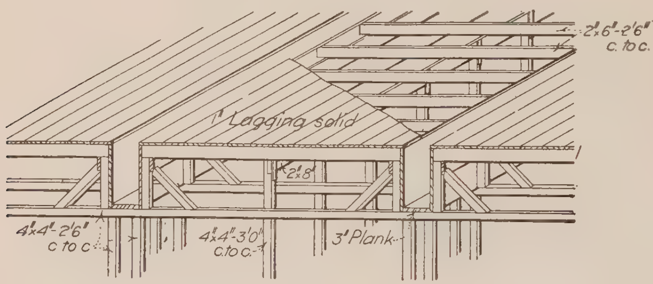


FIG. 3.—DETAIL OF CENTERING FOR LONG SPAN GIRDERS. GYMNASIUM FLOOR.

designed of Bethlehem steel girder sections, reinforced with top and bottom covered plates and fireproofed. The size of the steel girders was 30 ins. deep, 200 lbs. per ft., with two cover plates on each flange, one $\frac{5}{8} \times 15$ ins. and one $\frac{1}{2} \times 15$ ins. We obtained bids from the building contractor for the difference in cost of these girders, we having likewise made an estimate of the difference in cost. The contractors' price for them was $6,500 additional to his contract, although our estimate of the difference was somewhat less, being $4,664, based on prices obtained from outside sources. Taking our figures as a basis, as there are 5,400 sq. ft. in the two floors, the difference in cost for the structural steel, fireproofed, is 50 cts. a square foot more than the reinforced concrete, with no increased advantage.

The weight of the structural steel for a girder as compared to the weight of reinforcing metal is as follows:

Total weight of steel girders, with strap iron reinforcement for fireproofing and bearing plate, about 17,000 lbs.

Total weight of reinforcing metal in one reinforced concrete girder, 36 ins. deep, 5,500 lbs.

This shows that it takes about one-third the amount of metal for reinforced concrete as compared with structural steel for

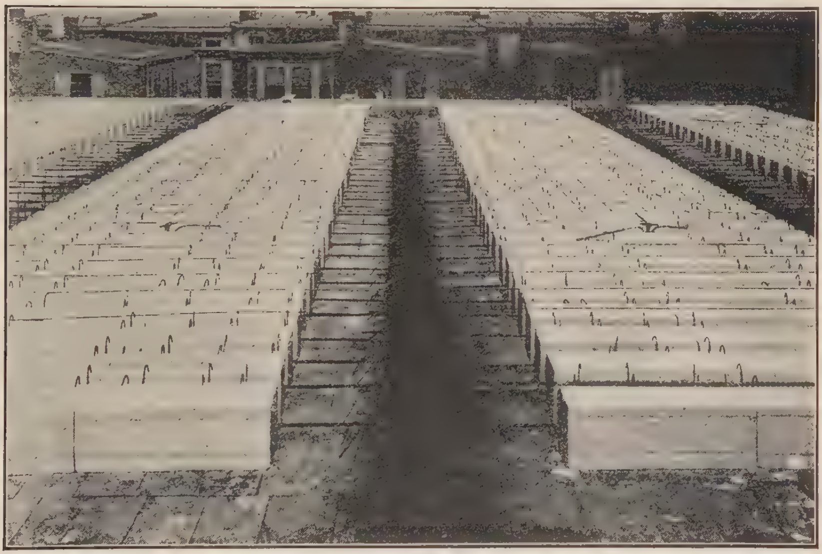


FIG. 4.—PLASTER BLOCKS IN POSITION ON FORMS.

girders and beams. The amount of saving in concrete would be the overhanging portions of the T head, which amounts to 2¼ yards per beam, when the extra thickness of concrete on the girders is taken into account due to the wide flanges on the steel girders; likewise there would be additional plaster blocks necessary to take the place of the T head omitted, the cost of which would have to be deducted from the saving effected by omitting the T head.

The sub-contractor for the reinforced concrete work gave

the cost of the plaster blocks, delivered at the job, as 14 cts. per sq. ft., and setting of same, including the nailing on of a fine wire screen at each end to prevent the concrete running into the hollow part of the block, as 3 cts. per sq. ft. additional.

The plaster block weighs 25 lbs. per sq. ft., as compared with 40 lbs. per sq. ft. for terra cotta tile, which cost the same price as the plaster block but which are not as easily handled, being only 12 ins. long, whereas the plaster blocks are 3 ft. long and can be sawed to fit any position. The walls of plaster blocks are about 1½ ins. thick, and there are two cells in each block, separated by a vertical wall in the middle which strengthens the block, so that traffic can take place over them before and during the time of pouring the concrete.

Immediately before pouring the concrete, it is necessary to thoroughly soak the plaster blocks with water, as they absorb a considerable quantity of water from the concrete if not thoroughly wetted; in fact the parts of the floor where the blocks occur and where they do not are clearly marked during the earlier stages of the setting of the concrete by the difference in its color, the concrete which does not come in contact with the plaster requiring more time to set.

For moderate spans, the use of concrete joists with either the plaster block or tile filler are desirable, where a flat ceiling is sought and the load light.

THE PREPARATION OF CONCRETE—FROM SELECTION OF MATERIALS TO FINAL DEPOSITION.

By Harry Franklin Porter.*

The preparation of concrete is an art requiring as much exact knowledge, experience, skill, and painstakingness as the preparation of steel. It is, if anything, a more difficult art, as the latter is carried on under fixed conditions and everything favors the reduction of the process to a science, while the preparation of concrete seldom takes place under conditions twice alike. In the first place, the materials themselves vary greatly, from place to place, and from time to time, differing in composition, quality, size, and grading, and in the second place, the assembly of the various materials that go to make up the composition of concrete, and their final deposition as concrete, involves a continual readjustment of the *modus operandi*. To prepare concrete properly, therefore, it becomes very necessary,

(1) To make a careful investigation of available materials before each and every use, involving an analysis to determine fitness and a synthesis to fix upon the proper proportions to ensure the desired results.

(2) To see that every reasonable precaution is taken, in the several operations incidental to installation, to ensure proper handling of the materials, both before, during, and after mixing, until the finished product is in place, and thereafter to see that it is left to solidify under the most favorable conditions possible.

Formerly the notion prevailed that concrete could be made out of any old materials by anybody anywhere at any time, provided only sufficient amount of good Portland cement were used. That no idea could be more fallacious, those most familiar with the practice are now agreed, but it has taken much sad experience to enforce the lesson; and it will probably take con-

* Consulting Concrete Engineer, Bridgeport, Conn.

siderably more before the lesson is fully, finally, and universally learned. Indeed, those who have had the widest and longest experience with concrete are of a mind that the preparation of this product, so far from being one of the simplest and easiest propositions, is one of the most complex, and that no large-scale process under human supervision requires a higher order of intelligence and skill. In no other building art is eternal vigilance so much the price of success. Concrete construction is of all construction the most practical; it is a success or a failure, just as the element of intelligence is present or lacking in any or all of the details from the selection of materials to the final deposition in the molds.

In order to undertake successfully—and successfully means intelligently—the preparation of concrete, it is, of course, first necessary to understand the principles involved.

It may be stated that the chief aim of concrete preparation is to secure as dense and homogeneous a mass as possible, by which it is meant that there shall be the closest possible contact between particles, and that the particles shall be so sized as to reduce the voids to a minimum.

To secure a dense concrete is not commonly stated to be the purpose, but a strong and durable concrete. As a result of these and similar misconceptions of the primary object, we find people trying to make strong concrete by the simple addition of cement, in other words measuring the quality by the proportion of cement to other ingredients, richness in cement being regarded as compensation sufficient for any and all other deficiencies; and trying to make waterproof concrete—which is dense concrete—by the addition of divers patent waterproofing compounds. The writer is of the opinion that, even as an ounce of common sense is worth a ton of cure, so in the preparation of concrete, if proper attention is given to securing as dense a mass as possible through the scientific grading of the inerts, abundant strength can be had with a minimum of cement. Nor do efforts spent in the direction of enhancing the density necessarily increase the cost. As a matter of fact, regarded even from the standpoint of first cost, enhancing the density decreases the cost, whatever expenditure entailed by the investigations to determine a scientific sizing

of inerts, and in practice to realize the result of the finding, being more than compensated for by the saving in cement alone, to say nothing of the economic value of a concrete at once denser, stronger, more durable, and practically waterproof. The primary object of making concrete, as well stated, is to secure a mass of maximum density.

To secure a dense concrete two things are necessary: (1) To effect, by the manner of sizing and proportioning the inerts, a maximum reduction of voids; and (2) to fill all pores, interstices, or voids remaining after the reduction as above with an elastic, insoluble, and tenacious substance, which must first have the property of a liquid, so as to flow freely into place, secondly, that of a glue, to unit all particles into a homogeneous whole, and thirdly, that of itself becoming hard and stone-like.

It is not possible, no matter how carefully and to what minute extent the grading of inerts is carried, to therewith alone eliminate virtually all voids. The various inerts, as they come for use in concrete mixtures, have voids roughly as follows: Broken stone, one size, 50 per cent.; broken stone, two sizes, not greatly differing, 45 per cent.; gravel, one size, 50 per cent.; gravel of indiscriminate sizes as found naturally, 30 to 40 per cent.; natural sands, 30 to 40 per cent.; artificial (crushed stone) sands, 35 to 45 per cent. Thus, on the average, inerts as they come naturally to hand have one-third to one-half of their volume as air-space, or voids. Ordinarily, by combining broken stone or gravel with sand, in certain proportions, usually about two volumes of the former to one of the latter, it is aimed to reduce these voids, not entirely or even as much as possible or advisable, but only somewhat. This somewhat may reach as low as 15 per cent., if the finer inerts as the sand, are particularly well graded naturally; more often it is not less than 25 or 30 per cent. The balance, whatever it may be, is then offset, as best may be, with cement. A typical specification for such a mixture would read:

"The voids in the coarse aggregate are to be filled by an equivalent volume of fine aggregate, and enough cement is to be supplied to fill the voids in the fine aggregate with (say) 10 per cent. excess."

Or it might be stated more simply and specifically as

"The concrete is to be proportioned 1 part by volume of cement, to 2 parts sand, to 4 parts broken stone."

Of these two specifications, both of which are typical of average practice, the former is the more scientific; but neither is scientific enough to ensure consistently good results—the object, presumably, we are after. In the first place, statement of the proportion of cement by volume measurement is exceedingly slipshod, for it ignores the fact cement dry from the bag, cement packed down, and cement mixed with water, have volumes respectively that differ widely, and that it is the volume of cement with its requisite water that should be taken into consideration; secondly, that there is no accurate or real distinction between coarse aggregates and fine; and thirdly, that actual voids in aggregates is a variable quantity, differing practically, not only with every job, but from day to day on the same job, even from hour to hour.

It is some improvement to state the proportions, as many engineers are now doing, as one part cement to so many parts aggregate, making no longer a distinction between fine and coarse aggregates. But this even is not enough. A specification to be proper should state, firstly, the maximum size of inerts allowable; secondly, the maximum voids; and thirdly, the quantity of *cement paste* necessary to effect a final filling of the voids and fulfil the requirement of a binder for all particles.

The maximum size of inerts, as governed by the mixing of the concrete proper, is fixed usually by the conditions of practice. It is of advantage to have it as large as practical, since the larger the individual volume the less, relatively, the superficial surface to be coated with binder. This follows from the fact that, whereas the volume of solids increases as the cube of the diameter, the surface increases only as the square. Three considerations, at least, work to limit the maximum size of inerts:

(1) The incorporatability: no particles should be used in the mix proper that will not readily merge with it.

(2) The width of members that are to be cast.

(3) The location and spacing of the reinforcement.

By the first consideration the size is limited to about 2 ins.;

and by the other two, on occasion, to as fine as 1/4 in., and seldom, in reinforced work, is larger than 3/4 in. practicable. Two in. stone, even, are not easy to mix, and it is probable, for best mixing, not larger than 1 to 1 1/2 in. should be used. Other grades of inerts are then to be supplied of such sizes and amounts as to effect a maximum reduction of voids. It is entirely possible to reduce the voids to 10 per cent. and even less; but probably 10 per cent. is a practical minimum. To fill the remaining voids cement must be largely relied upon.

Not many sizes of inerts are needed. Suppose the maximum is fixed at 1 in.; then, as has been found experimentally and may be demonstrated analytically, the next size smaller should be, in order to fit easily into the voids of the maximum size, approximately one-fourth as large, that is, in this case, 1/4 in., and there should be about one-half as much of them. The next size should be approximately one-quarter of the second, viz., 1/16 in., and a volume of them equal to one-half the second size, or one-fourth the first; and so on, down to impalpable dust. Probably there will not be more than 4 or 5 grades altogether, the finest grade comparing with cement in fineness, finer than which it is scarcely possible to go. This law of grading, if represented by a curve, would assume the form of a parabola, having its origin at the intersection of zero size and zero proportion, and approaching coincidence with the horizontal at the intersection of the 100 per cent. ordinate and the maximum size abscissa. It will be found that the intersection of the 50 per cent, ordinate and 1/4 maximum size abscissa, and the intersection of the 25 per cent. and the 1/16 size, and so on as outlined above, will fall on or near the parabola.

By use of such a curve, and the separation of a combination of inerts proposed for use into several grades down to dust, plotting the results alongside the standard curve for comparison, the deficiencies can be at once recognized;—whence the extra proportion of any one or more sizes, or the proportion of a size not present, may be readily calculated, and the deficiencies corrected.

If there is an excess of coarse aggregate the curve will be too flat; if an excess of fine, too high. An excess of fine is particularly objectionable in that it crowds the cement grains and prevents their working properly; moreover, it requires an excess of

cement. An excess of cement is also required when there is an excess of coarse aggregate. Unlike the other condition, however, there is no crowding of the grains. The cement still does not function properly, in that it is congested in the large voids instead of being distributed in their films and fine points, forming, as it were, an interlacing meshwork, entwining all particles.

Best results obtain when the grading is uniform, from maximum to dust, but with no more than 10 per cent. of the finest grade, which approximates the cement in size and may be regarded as replacing so much of it as finest filler. The cement when made into a liquid with water, will have only to coat all particles with a thin film and to bridge the few small remaining interstices. Nothing but a liquid can perform this office; this is an important point and will be referred to later.

Another point is not to have the aggregate of too near the same sizes such as a mixture of 1 in. and ¾ in. stone, for the reason that the smaller will crowd the larger, preventing it from assuming the most compact form; in fact, even so large as ½ in. will crowd the larger size. The desideratum is (1) that the maximum size should be free to assume its most stable configuration, which is when all particles are in as close contact as possible; and (2) that the next smaller size should just be large enough to neatly fill the maximum interstice, and that there should be just enough of this size to fill all these interstices. Similarly, the next smaller size should be such in dimension and amount as to effect a complete filling of the next largest interstice, and so on.

If this law of grading is observed, it will be found that the final total volume about equals the original volume of the maximum size, and that mixture will be the most dense of which this is the nearest true.

This points to a practical way to determine upon the best proportions, and that is to try a number of different combinations of the materials available, and to use that one which gives the least volume, or the one nearest the size of the volume of the maximum size particles alone.

The sufficiency of fine particles, and of the cement, may be simply gauged at the same time, provided complete mixtures are

prepared, as is indispensable to accurate gauging even of the inerts, for the particles, no matter how well graded, are not free to slip and slide into the position of maximum stability (closest contact), until assisted by the lubrication of the cement cream. It is an indication of sufficiency of fine material when the voids in the coarsest material are just filled, such that when tamped lightly a soft mush flushes to the surface. It is an indication of sufficiency of cement when this fine material presents a smooth, glossy appearance: that concrete or mortar is the densest which appears the smoothest.

The test mixture should be so soft as to quake like a jelly, and be ready to flow, for the above indications as to quality to be apparent. Similarly, during the deposition of concrete, if it is of a proper liquid or semi-liquid consistency, the trained eye of the foreman or supervisor can keep track of the quality of the mixture almost as accurately as an automatic proportioner, supposing there were such an instrument. As a matter of fact, there is no satisfactory substitute for the trained eye of the foreman, nothing that can detect so quickly and accurately any variations in the composition of the mixture, as occur often many times in a single day on the average concrete job, due to variations in the material or to mistakes of the workmen.

Another way to gauge the accuracy and sufficiency of the grading is by weighing. The mixture weighing the most relatively, is the densest. If the solidity of the concrete were absolute, that is, if the voids were completely filled, its weight would be in the neighborhood of 165 lbs. per cu. ft., if the inerts were of quartz, 170 lbs. if of limestone, and 180 lbs. if of trap.* A few pounds are to be allowed for shrinkage, say 2 lbs. per cu. ft. for moderately wet mixtures, so that if measurement and weight are taken wet, this correction should be applied before estimating the density. There will be a loss by evaporation, if the concrete is allowed to harden exposed freely to the air; if wet-blanketed, there will be practically no loss from this source. A weight of 160 lbs. for quartz concrete, hardened under favorable conditions

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*Bulletin 344, U. S. Geological Survey, shows under laboratory conditions, the following average weights in lbs. per cu. ft. for concrete of the aggregates stated: Cinders 115, Granite 148, Gravel 142, Limestone 146. Proportions: Cinders 1:3:5, others 1:2:4.—ED.

of wetness, with shrinkage allowed for, can scarcely be improved upon. This means a solidity of 97 per cent., or a reduction of voids to 3 per cent. A concrete this dense will be found practically impervious to water, even under considerable head, indeed to the limit of its strength. No more can be asked, nor can the admixture of any special compound show results superior.

The size of inerts is not necessarily limited to the maximum stated; if conditions permit as large stone as it is convenient to handle may be intermingled with the mass, so long as there always is an abundance of concrete or coarse mortar to completely cover them. Such stone are called bulk swellers, to distinguish them from ordinary inerts.

Bulk swellers should not be less than 4 diameters larger than the largest inert, and preferably still larger, in order that there may be no doubt as to the fine material slipping into the voids. Especially if the volume of bulk swellers is sufficient to cause the concrete proper to occupy the relation to it of a filler of voids; but they should in no event be less than 4 times larger, lest they act merely to displace or crowd the coarsest inerts, rather than an equivalent volume of all inerts. If the bulk swellers are so sized, a volume of them may be used equal approximately to twice the volume of the concrete proper. Of course, bulk swellers being generally added subsequently and individually, relative volumetric considerations scarcely figure, but coarser particles may be added up to the point where there ceases to be a sufficiency of fine material to thoroughly imbed them.

The maximum size of bulk sweller is fixed only by the character of the work and the capacity of the plant for convenient handling. If the work is massive in character, as a bridge pier or abutment, and a derrick is handy, as large stones may be used as the derrick can conveniently manage. Ordinarily, however, no larger than one man stone should be attempted, as it will not be found economical; again, conditions may be such as to make even one man size, or any bulk swelling material at all outside of what can be incorporated in the mixing, uneconomical.

There need be no especial concern as to big stone settling through the soft concrete and congesting at the bottom, for there is so little difference in the density that large stone will tend to

float like a log in a pool, almost but not quite submerged. As a matter of fact, excessive agitation of a mass of concrete tends, by the principle of buoyancy, to force the large particles to the surface, that is, if the mass is well proportioned and not too thin. Of course, if the mixture is light and watery, the action will be reversed and the large particles will tend to congregate at the bottom. These matters all indicate the importance of a properly balanced mix, a proper consistency, and careful manipulation throughout the sequence of operations.

When large stone are introduced into the mass, great care must be exercised to see that they are well distributed, with a comfortable margin of soft material all around. The danger is that the large stone, particularly if regular in shape, will segregate either across or up and down, introducing planes of weakness. It is also important that the stone be clean and thoroughly wetted, lest the adhesion be deficient.

The shape of bulk swellers is an important consideration likewise; cubical or square faced blocks are less desirable than irregular or well-rounded ones. Square edges act like so many wedges, tending to cleave the mass as in hardening it shrinks around them. Rounded stone, on the other hand, imbed themselves more naturally, the mass in shrinking tending to conform to their contour. Irregular shapes tends to key themselves in, and to prevent, rather than induce, cracking. Flat stones are less desirable even than cubical ones, as their tendency to induce splitting is still more pronounced. These objections on the score of shape constitute in fact the greatest drawback to the use of large bulk swellers.

An interesting example of the use of large bulk swellers is afforded in the construction of the piers and abutments for the new concrete arch bridge across the Rocky River at Cleveland, Ohio. In this instance huge pieces of rock, as large as could be swung into place with a derrick, were introduced into the mass at frequent intervals, being first cleaned, dusted and wetted. Advantage was taken of these stone, at the conclusion of any period of operation, by leaving them protrude about one-half, thus providing an admirable key for the subsequent work. It is an interesting fact that, although frequently square faced

stones were used, no unfavorable shrinkage action showed itself, which would indicate that most of the shrinkage must take place while the concrete is still plastic enough to conform to the rigid outline of the contained block without separating. Hence the tendency to induce cracks may not be so serious a matter as might be supposed.

There is another advantage in the use of bulk swellers of irregular shapes, especially in that they act as reinforcement, forming here and there throughout the mass, so many rigid keys locking the parts together, and in this way enhancing both the compressive and tensile strength, if not very much in the long run, at least an appreciable amount on short time. Of course, just how much strength will be added in this manner depends largely on the character of the stone itself. This enforces the necessity for a good quality of stone for concrete mixtures.

Bearing on this point, investigations made in connection with one of the bridges recently constructed by the city of New York, to ascertain how the strength of concrete might be increased so as to act as an adequate filler and stiffener to some cast pedestal, are of interest. It was found by the addition of a certain number of cut nails or spikes per cu. ft. of concrete, the crushing and tensile strength were increased enormously, one series of tests giving results as high as 18,000 lbs. per sq. in., or nearly eight times the ordinary strength.

Similarly, by the plentiful intermingling of large, irregular shaped, more or less elongated, tough bulk swellers to a mass of concrete, it would appear that the strength must benefit no slight amount. In reinforced concrete work, especially, this principle might well be taken advantage of, providing, of course, conditions are favorable to it, to the end that the concrete act further with the steel to resist tension, thus increasing the actual strength of the whole member. Indeed, it is not at all improbable that, in the no very distant future, reinforcement of this nature, that is supplying resistance to particles throughout the mass, by introducing here and there short pieces of steel, on the tensile side especially, will come into use, thus making concrete a more truly homogeneous structural material. The same prin-

cipal might also on occasion be taken advantage of in columns, in order to keep down the girth and avoid the necessity of steel cores.

All concrete may be looked upon as a combination of mortar with bulk swellers. Thus the conventional 1 : 2 : 4 mixture might be regarded as composed of 1 part 1 : 2 mortar and 4 parts bulk swellers. The correctness of the rule as to the proportion of bulk swellers allowable, a volume of them equal to twice the volume of fine material, is now apparent. What, then, it may be asked, is the practical use of regarding the bulk swellers separately? Just this, that they play no vital part in the proper balancing of the inerts from coarse to fine to secure a dense concrete, it is the fitness, largely, of the mortar in any concrete that determines its density.

This would indicate the feasibility of a standard concrete mixture, one which might be used for any and all purposes, differing only in the proportion and size of the bulk swellers added. It would be only necessary to agree upon the most suitable and convenient maximum size inert in the concrete proper. Larger than 1 in. would scarcely be possible, as already pointed out; probably 1 or ¾ in. would best satisfy general requirements. The preparation of good concrete, then, would resolve itself into the selection of suitable finer grades of material to compare with the maximum grade determined upon. Efforts in the direction of economy, instead of expending themselves in such unworthy ways as skimping the cement, would be confined to improving the grading, and to incorporating with the mass, either during mixing or thereafter, as many and as large bulk swellers as conditions favor and judgment approves. If bulk swellers are added during the mixing, they should be held out until the rest of the material is pretty well intermingled. No specific limit need be set as to their amount relative to a stated volume of fine material (as measured mixed), except to rule that no more of them shall be added than can be readily incorporated. An approximate ratio has already been given, but this may not always indicate the true proportion, more or less; judgment on occasion is the best guide.

There remains to discuss the function of the cement, about

which there apparently prevails much misapprehension. Just what does the cement do, and how does it do it? These are common questions which demand specific answers.

What is known to the trade as Portland cement is a mixture, partly chemical and partly mechanical, of lime and silica in certain well-defined ratios. Pure Portland cement, would consist, according to S. B. Newberry,* wholly of tri-calcic silicate 3 $CaO\ SiO_2$, which compound may be regarded either as a chemical combination or as a solid solution of lime in silica, even as brine is a solution (but a liquid one) of salt in water. Practically Portland cement contains several other compounds besides the tri-calcic silicate. In the first place there will be analogous aluminates and ferrites, and magnesium silicates, aluminates, and ferrites; and in the second place some of the lime and silica will not be combined at all. One has but to feel a cream of cement to detect the presence of uncombined silica. Of course it is aimed to keep these other compounds present in as low amounts as possible, especially the magnesia, more than 4 per cent. of which is considered harmful and is prohibited by the specifications. Alumina and iron are less objectionable, and, while adding perhaps little or nothing to the cementing value directly, they serve a valuable purpose as a flux in calcination, greatly facilitating the combination of the two essential compounds, lime and silica. It is aimed to use no more iron and alumina than absolutely necessary to a satisfactory flux at normal kiln temperature. Again, not all of the lime and silica, nor of the analogous compounds, are combined in the tri-valent form. There is generally some formation of bi-valent compounds, such as 2 $CaO\ SiO_3$, the value of which in the product is not definitely known; the higher the temperature at which clinkering takes place the more likelihood that only the tri-valent order will be formed; and the more tri-valent calcium silicate formed the better the cement. Taking all these factors into consideration, probably of the average first quality Portland cement, not more than 75 per cent. has any real cementitious value, the balance represents so much inert matter.

Tri-calcic silicate, assuming it to be the essential compound,

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* *Journal Society of Chemical Industry*, Vol. XVI, 1907.

is only potentially cement; it is not actually cement until after its union with water. The dry powder, marketed as Portland cement, is in truth no more cement than the water with which it is finally combined. The two substances occupy the same relation to one another as does nitric acid to gylcerine, neither of which alone has any explosive value, but together—as nitro-glycerine, or dynamite—they form a very powerful explosive. The real cement, then, is the compound that results upon the addition of water. It is composed of calcium, silica, and water (H_2O), so combined as to form a very stable compound. Tri-calcium silicate itself is a very unstable compound, being heavily surcharged with basic valencies. Calcium is a base, silica an acid and water an acid in the part that they play in chemical reactions. We have this, therefore, as the result of the interaction of ultra-limed silica and water, in order to produce a stable neutral substance, $3\ Ca + SiO_2 + xH_2O$, the proportion of water being such as, with the silica, to just equalize the lime chemically. Six molecules of water combined with one of silica will approximately balance, in molecular weight, three molecules of lime.

This compound which may be known as calcium hydro-silicate or hydrated silicate of lime, in solidifying out from a heavily concentrated solution at moderate temperatures, assumes a gelatinous condition. Other compounds present form crystals, which intersperse themselves in the jelly like so many splinters in a daub of glue, and add little if any strength to the mixture. Moreover, they are more or less soluble, whereas the jelly, once it has hardened, is virtually insoluble. This jelly or *gel-colloidal* hydro-calcium silicate, is the true cement. It is indeed a mineral glue. Coating all particles and filling all voids, on hardening it contracts drawing all parts into the closest possible relation and forming a dense, impervious, homogeneous solid. For our knowledge as to the formation and action of this *gel* we are much indebted to the German analyst Dr. W. Michaelis, Sr., whose painstaking inquiry into the nature of cementitious action covers the better part of a lifetime. Dr. Michaelis has always contended strongly for the mineral glue theory; now practice seems about to bear him out.

The importance of having a densely graded aggregate, in the

light of the mineral glue theory, assumes added weight; also the futility of cement as a filler merely gains greater emphasis. Cement as a glue is scarcely more potent as a filler of large voids than is ordinary glue to compensate for unevennesses in two boards; and even as in the case of ordinary glue the greatest adhesion is developed when the layer of glue is the thinnest, or which is the same thing, the contact of the two surfaces is most perfect, so in concrete the greatest strength is secured with the most densely graded aggregates, requiring a minimum of cement.

To promote the formation of colloidal calcium hydro-silicate, then, becomes of paramount importance in the preparation of concrete. Not only is this compound, once hardened, practically insoluble, but being a *gel* it effectually seals all pores, thus making the mixture impervious.

The formation of *hydrogel,* as this compound may briefly be known, is most promoted by heat. It is also promoted by agitation. It is seriously retarded by cold and excessive wetness. Indeed, at low temperatures or from weak solutions, the colloidal form is scarcely assumed at all, inferior crystalline shapes asserting themselves. These facts indicate the conditions that should surround the preparation of concrete. Evidently, in the mixing, the agitation should be very thorough, in order that the water and cement powder may be brought in closest possible contact, but there should be very little heat, lest premature hardening ensue, heat very greatly accelerating the action. Hence, if heat cannot be conveniently avoided in the mixing, as it scarcely can on a hot summer day, some measures become necessary in order to delay the hardening. A good way is to make the mixture over-wet; another, to cover the freshly mixed material as it is transported from the mixer to deposital with wet cloths (burlap is excellent for this purpose). Also the completed work must be covered to shield it from the direct rays of the sun, and as soon as hard enough to bear it, wet-blanketed, with moist rags, sand, saw-dust, or some such. Otherwise, the surface will harden so much faster than the interior as to seriously warp and twist the mass, perhaps also crack it. It is of the greatest importance that hardening should take place uniformly.

If, after the molds are filled, heat could be applied so as to

raise the temperature of the mass evenly throughout, the formation of *hydrogel* would be markedly promoted, and the hardening go forward thereafter with great rapidity. But, ordinarily, such a measure is practically impossible; moreover, it is not nearly so necessary in warm weather as in cold,—in late spring, summer, and early fall as the rest of the year.

When the temperature falls below 40 degrees F., the formation of *hydrogel,* no doubt, scarcely takes place at all; neither, for that matter, does crystalline formation, what crystals that may form being probably flat and polygonal, rather than slender and needle-like, and so of little value cementitiously. The very chemical activity engendered by the contact of the two affinities, water and cement powder, however incipient, generates some heat and thus promotes the formation of needle crystals and colloids.

If, however, concreting is to be carried on in the neighborhood of the freezing point, it is not sufficient to lower the freezing point of the water, as is commonly practiced, by the addition of salt or calcium chloride, but it is quite necessary to apply heat in some manner to the concrete after placing, sufficient to raise the temperature of the whole mass to a point where favorable formation of *hydrogel* can take place. This temperature should not be less than 40 degrees F., and perhaps a minimum of 50 to 55 degrees F. should be stated; at any rate, vigorous action does not set in until 75 to 80 degrees F. is reached. Such a temperature, of course, is scarcely possible of realization in practice, except the outside temperature itself be as high; but it should be approximated as closely as possible.

There are a number of methods in vogue for heating the concrete in cold weather, but it is beyond the scope of this paper to go into detail with regard to them. Perhaps the most efficient, certainly the most elaborate, on record, was that used in the construction of the Butler Brothers' mammoth new warehouse in St. Louis. In this instance not only was heat applied underneath by curtaining off the wall panels and runing salamanders within, but the entire scene of operations was tented over and kept, by means of salamanders, at a temperature of about 55 to 60 degrees F. Thus the concrete during deposition and for

several days thereafter (nearly a week) was protected by a blanket of warm air both above and below. Very pleasing results were obtained.

It is not always necessary, at least it does not always pay, to protect the work so thoroughly as in the Butler Building. Often it is only necessary to deck over the freshly deposited concrete with boards and canvas leaving an air-space underneath of 1 or 2 ft., and heating by the introduction of steam pipes. The pipes should not lay too close to the green concrete, being blocked above it at least 6 ins. or insulated therefrom by planking, for the heat in direct contact or nearly so is distinctly unfavorable to the cement. This method is especially adapted to massive wall construction. In building construction it is generally necessary also to heat underneath the centering; and again, heating underneath and decking without heat above, may suffice. It depends somewhat on the thickness of the members, but mostly on the severity of temperature conditions. It is no matter if the concrete freezes slightly in transportation, so long as it is thoroughly mixed first and sweated out as soon as possible after depositing. Of course, if the freezing is considerable, such that the material reaches the forms all balled up, it must be thawed out at once in order that it may flow to place properly. A live steam line is often of great service in this connection. Needless to state, no concrete should be placed in forms in which there is ice; here again the live steam is most useful, being applied to the forms just before filling. These and similar precautions and measures are indispensable to success in all cold-weather concreting.

There are other things that contribute in degree to the strength of concrete mixtures, as for instance the amalgamation of uncombined lime in the cement with silica in the inerts, or of uncombined silica with lime, either a part of the inerts or introduced purposely, in the form of a powdered hydrate (never quicklime), both of which combinations are promoted by heat and agitation. The compound thus formed is also *hydrogel,* a formation of which always takes place when lime and silica, in finely powdered condition, are brought together in solution. This points the way to the value of hydrated lime used in conjunction with Portland cement in concrete mixtures; there is always con-

siderable excessively fine silica present, some in the cement itself, other in the inerts; by adding, therefore, a proportion of lime hydrate some of this silica can be combined to increase the formation of *hydrogel*. The value of limestone dust, mingled with the inerts primarily for the purpose of perfecting the grading, is also hereby indicated, the lime uniting with the silica in the presence of water to form of itself a cement, improving the adhesion and decreasing the permeability. The same fact affords an explanation of the superior strength (but not permanence) of limestone concretes as sometimes noted. It seems that all concrete mixtures would be improved by the addition of a proportion of powdered lime hydrate, but it is uncertain as to how much, or what proportion of lime may be used as compared with the proportion of cement. Mr. L. C. Sabin, United States Government Engineer, reports the results of certain experiments made under his direction whereby the replacing of a quarter of the cement with hydrated lime, so far from diminishing the strength, increased it nearly 100 per cent., besides increasing the impermeability, and the replacing of so much as fifty per cent. was found to increase the strength half as much, or nearly fifty per cent. These are valuable indications, and in the light of the present context appear entirely reasonable. Hydrated lime, at any rate, aside from the question whether or not it enhances the strength, certainly is a valuable adjunct to water proofness; indeed, if any compound is to be added to the mixture for this express purpose, it is doubtful if there is anything superior to it.

As to whether solidified calcium hydro-silicate is the final product of hardening, it is difficult to say; probably the eventual is a conversion of all the lime into carbonates, by absorption of carbon dioxide from the air, or from the contained water in the solution, and of all silica (also iron and alumina) into hydrates, the strength continuing to increase until the conversion is completed.

REPORT OF THE COMMITTEE ON CONCRETE AND REINFORCED CONCRETE.

By Alfred E. Lindau, Chairman.

The Committee is not prepared to make any definite recommendation, and will confine itself principally to a review of some of the more important features affecting the use of reinforced concrete.

The adoption of a standard practice* in reinforced concrete, is in itself a distinct advance over the chaotic conditions existing some years ago. It is, however, unfortunate that these standards or rules of practice, which being adopted to cure existing evils and to a certain extent the result of an attempt to harmonize a number of conflicting views, have been worked out along lines so conservative as not always to have given full scope to the development of the art. Furthermore, the extreme limitation of fields covered by experimental research, has compelled the different organizations in charge of this work to base some of their conclusions upon purely theoretical grounds, while the very mass of experimental data accumulated along certain lines, has made its coalition so difficult a task, as to make it unavailable in crystallizing the results into rules of practice. On the other hand, reinforced concrete in common with other types of construction has developed along the lines of commercial necessity requiring the most efficient possible use of the materials available, and owing to this very lack of recognized rules of practice, such rough and empirical methods as load-tests, comparison of proposed with existing structures, etc., have been depended upon to insure proper construction. The same commercial necessities have compelled every advantage to be taken of the constructive possibility of this material, so that the typical reinforced concrete structure of to-day in place of being merely a combination of simple beams and columns, that have so far been the basis of the largest part of experimental and theoretical work, is frequently a structure of

* See *Proceedings*, Vol. V, p. 454; also Standard No. 7.—Ed.

extreme complexity. The results of practice, however, seem to prove that the structural members are even stronger than the carrying capacity computed according to the recommended rules of practice.

The situation is that a difference of opinion exists between the organizations, which have been delegated to recommend rules of practice and practical constructors who have been forced to consider commercial conditions. It would seem advisable for an association of this class, whose interest is in the practical use of reinforced concrete, to attempt to secure a reconciliation between these varying points of view, to secure consideration on the part of the theorist of the results of the practical constructor and on the part of the latter a fuller recognition of the theoretical principles underlying the development of the art. This matter is considered of sufficient importance by the Committee to give an outline of the principal differences existing between the rules and existing current practice. These differences cannot, of course, be outlined as clearly and definitely as could be desired because of the variation in practice corresponding to the varying commercial conditions throughout the country. At the same time it is possible to broadly outline some significant points where this conflict is in evidence, and to present a certain amount of experimental data upon the points now most clearly in dispute.

The close competition and intense activity in concrete building construction naturally concentrates attention to limitations affecting the amount of material used. The allowable working stresses in the metal and in the concrete have therefore received more attention than any other recommendation.

Fixing satisfactory values for the tensile stress in the reinforcement of a concrete beam presents some difficulties owing to the fact that concrete cracks at comparatively low stresses in the metal. The metal stress at which concrete cracks being in fact, so low that economy prohibits this consideration as a limiting condition, consequently the question resolves itself into fixing a limit having a proper factor of safety against ultimate failure and the size of the crack that may be allowed to prevent the corrosion of the steel by atmospheric or other influences.

Laboratory tests have been made to show the effect of atmospheric corrosion in beams where the stress in the metal varied

from the usual working stresses to those beyond the elastic limit. Tests made by Mr. E. Probst in the laboratory at Gross-Lichterfelde in 1908 have been translated and briefly described and summarized in Appendix I. Examination of these results show that even a specially prepared corroding atmosphere is unable to produce appreciable effect on the reinforcement in the presence of cracks caused by metal stresses equal to the elastic limit or even beyond that point. This being the case there is good reason for fixing the allowable stress in the metal with reference to the elastic limit, rather than points at which cracks may be observed in the concrete, unless these cracks are so large as to be considered unsightly.

The apparently successful use of high elastic limit reinforcement, and the accompanying high working stresses used by many designers of recognized standing in answer to the universal demand for economy calls for consideration of a higher working stress than usually allowed for medium steel.

Based on the results of experience as well as experiment, there is a constantly growing tendency to disregard the compressive stress in beam action, having regard only for some limiting percentage of reinforcement which may be shown to be safe against compressive failure. It is quite probable that in establishing working fiber stresses in compression we have been guided too much by the results of compression tests on cubes and cylinders instead of on beams.

Moment factors for slabs incorporated on all sides into beams, for slabs reinforced in two directions and for girderless floors should be investigated by the Association, as the carrying capacity of slabs under these conditions seems to be largely in excess of that provided by ordinary rules of practice. In fact the committee considers it of great importance to collect available information along these lines and to this end presents the results of a few tests in Appendix II, which it is hoped will serve to throw a little light on this matter.

APPENDIX I.

Abstract of Investigation by E. Probst on the Effect of Rust Producing Gases on Reinforcement Embedded in the Concrete.*

One of the important questions regarding reinforced concrete is the effect of corrosion on the reinforcement, more particularly in such structures or parts of structures where cracks of appreciable size may be found. It is not possible to so design reinforced concrete work as to entirely avoid fine cracks. These are frequently caused within the limits of the working stresses in the concrete and the steel.

The question that presents itself, therefore, is whether these cracks endanger the strength of the structure or impair its stability in the course of time. Should it be possible for a corroding atmosphere to reach the reinforcement through the cracks in the concrete, there would unquestionably be some doubt as to the life of the structure. In order to throw some light on this subject thirty-two beams were tested, these beams being 1.7 meters long, 16 cm. wide and 22 cm. high, reinforced with varying percentages and types of reinforcement.

A special testing apparatus was designed, shown in Figs. 1 and 2, and carried out in the following manner:

The test beams, *B B*, were placed in position at the same time, resting on bearings *a a* and having a clear span of 1½ meters. They were loaded at two points symmetrical with the center 0.50 meter apart transferring the load, *L*, in the scale by means of the lever, *H H*, the leverage being 1 to 5. The beam was loaded sufficiently to cause cracks to occur in the under surface of the beam. A perfectly tight case, *K*, of sheet iron was fitted around the beam between the two load points and connected by rubber tubes to a reservoir containing rust-producing gases. After a number of preliminary trials it was found that a mixture of pure carbonic acid, pure oxygen and steam produced rust in 24 hours. CO_2 and O were taken from the gas reservoirs and conducted through the bottles, *F F*, so that the amount of gas could be regulated by the valves, *V V*. The steam was generated in a little boiler by means of a gas flame. Other details are shown on the figures.

The principal object of the test was to use such rust-forming substances as are found in an attenuated form in the atmosphere and which also would give results in a very short time. The beams had all been previously subjected to a load of 6,000 kilograms (about 12,500 pounds), or with a load causing a stress in the steel close to the elastic limit,

* Mitteilungen aus dem Kgl. Materialprüfungsamt, Gross-Lichterfelde, 1908.

opening up cracks of considerable width. CO_2 and H_2O was applied for three days, after which the concrete was removed and the steel examined, with the result that no corrosion could be detected. Such preliminary

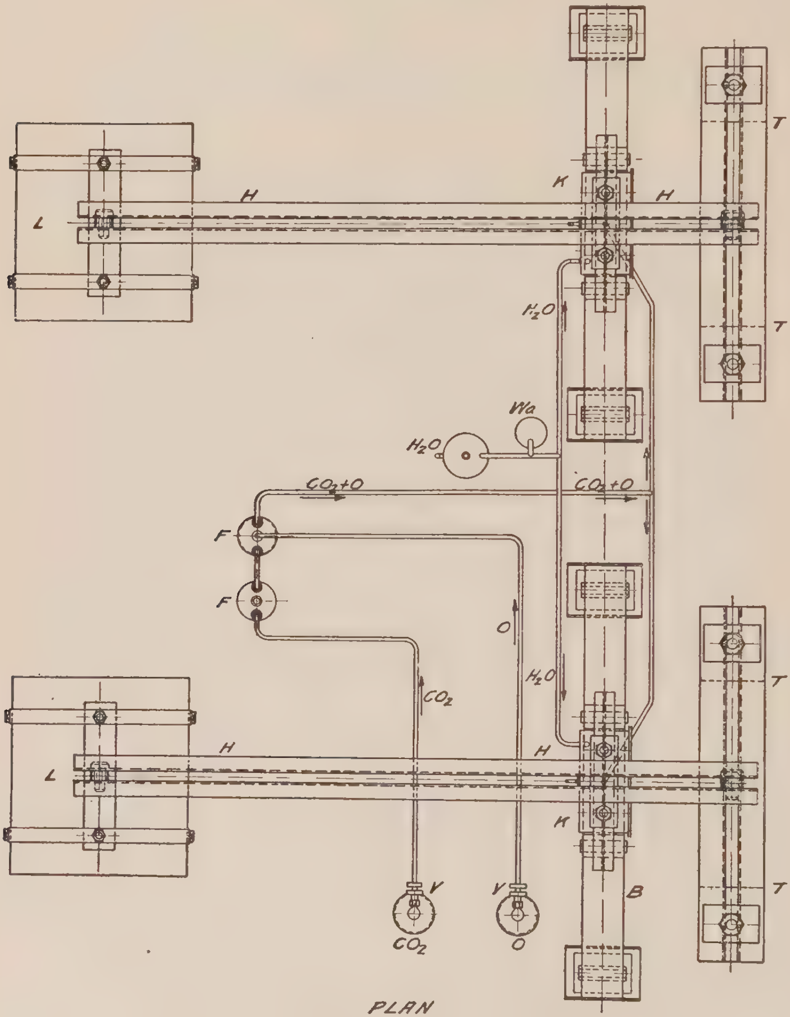

FIG. 1.—GENERAL ARRANGEMENT OF TESTING APPARATUS.

tests were carried out with several beams for two or three days. Only the application of oxygen, carbonic acid and steam could produce rusting and the CO_2 was applied in order to accelerate the effect.

Beam 38, which had previously been loaded with 6,000 kilos. and tested with a load of 5,930 kilos. in the corresponding atmosphere, was broken at the end of three days after being subjected to O_3, H_2O, and steam and CO_2 without showing any corrosion of the steel. In order to

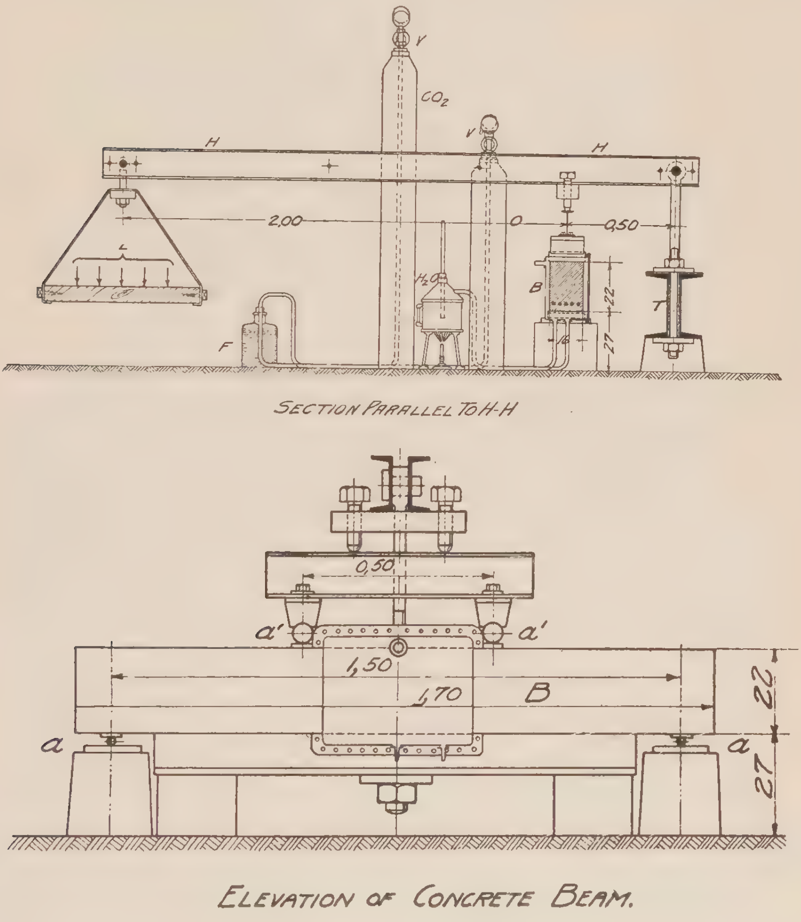

FIG. 2.—DETAILS OF APPARATUS SHOWN IN FIG. 1.

show the effect of this combination, a beam from which the concrete had been removed below the bars was put in the apparatus and after 24 hours all the bars were completely covered with rust, demonstrating that the above mixture very quickly corroded the steel, whereas CO_2 and H_2O alone were unable to do so.

To determine the corrosion of the reinforcement through cracks in the concrete the following investigation was made:

First, the beam to be tested was loaded to a point at which cracks appeared and then was put into the testing apparatus and loaded again.

TABLE I.—REPORT OF THE RESULTS OF THE RUSTING TESTS.

Mixture of gas in each case is $CO_2 + O + H_2O$, except Beam 54, where mixture is CO_2.

Beam No.	Age, days.	Preliminary Load, pounds.	Final Load, pounds.	Date of Application, 1907.	Time, days.	Effect.
21	134	10,000	10,900	III. 25–27	3	No rust could be found.
22	145	13,200	13,100	IV. 4–6	3	" " " " "
23	131	9,900	10,900	III. 25–27	3	" " " " "
24	144	13,200	13,100	III. 4–6	3	" " " " "
25	116	9,900	10,900	III. 11–13	3	" " " " "
26	116	9,900	10,900	III. 11–13	3	" " " " "
27	117	9,900	10,900	III. 14–16	3	" " " " "
28	117	9,900	10,900	III. 14–16	3	" " " " "
29	116	9,900	10,900	III. 18–20	3	" " " " "
30	116	9,900	10,900	III. 18–20	3	" " " " "
31	117	9,900	10,900	III. 21–23	3	" " " " "
32	117	9,900	10,900	III. 21–23	3	" " " " "
33	137	13,200	13,100	IV. 8–10	3	" " " " "
34	142	16,600	13,100	IV. 11–13	3	Along 3 larger open cracks intense rusting was found extending perpendicular to the reinforcement.
37	134	16,600	13,100	IV. 8–10	3	The concrete had moved along the steel so that a large horizontal crack occured. Here the bars were intensely rusted for a length of about 4″. At another place the rusting was about 0.6″ long.
38	139	13,200	13,100	IV. 11–13	3	No rust could be found.
40	171	13,200	13,100	IV. 15–17	3	" " " " "
41	143	15,500	13,100	IV. 22–24	3	A slight rusting was found where crack was.
42	156	9,900	10,900	V. 16–18 20–25 27–31	11	No rust could be found.
43	141	9,900	13,100	IV. 22–24	3	" " " " "
44	154	13,100	10,900	IV. 29–39	3	" " " " "
45	155	13,200	13,100	V. 6–8	3	Slight rusting at the cracks.
46	154	13,200	13,100	V. 13–15	3	No rust could be found.
47	181	16,500	13 100	V. 6–8	3	Slight rusting at the places of cracks
48	180	13,200	13,100	V. 13–15	3	No rust could be found.
51	102	13,200	13,100	V. 18–20	3	" " " "
52	102	13,200	13,100	V. 18–20	3	" " " " "
53	117	9,900	10,900	V. 16–18 V. 20–25 V 27–31	12	" " " " "
54	114	13,200	13,100	IV. 29–31	3	" " " "

Under a constant load the application of the corroding mixture was continued from seven o'clock in the morning until four o'clock in the afternoon every day, and during the night the boxes were removed and the cracks exposed to the air. After the expiration of the time fixed for the test all the concrete was removed and the steel investigated as carefully as possible, doubtful places being examined under a magnifying glass—it

might be mentioned here that the steel bars used in this test had been cleaned before embedment and were not painted with a cement mortar. The results are shown in Table I. It is interesting to note that the bars after the removal of the concrete where the rust spots did not show were as bright as before embedment.

Recapitulating the results, we find,

1. Up to a loading of 6,000 kilos., corresponding to a steel stress of 2,500 kilos per sq. cm., or about 36,000 lbs. per sq. in., no corrosion could be produced even with the most concentrated rust forming materials, in spite of the fact that the cracks opened up comparatively wide under these loads. The test of beam 53 was continued for twelve days under a load of 4,530 kilos. without interruption, and it was absolutely impossible to find any formation of rust.

Rusting could be produced only after the beam had previously been loaded with 7,500 kilos., which load is near the ultimate load of the beam, and in which case the steel had passed the elastic limit.

FURTHER REFERENCES.

Schumann* states that in cases investigated regarding the effects of carbonic acid and water on cement and discussing the destruction of cement mortar in spring water reservoirs, have always shown that

1. The water was very pure, containing few mineral substances.
2. The water contained at the same time free carbonic acid in solution.
3. The reservoir had to resist a constant flow of water.

Conditions 1 and 3 alone are sufficient to attack the cement mortar because very pure water dissolves and carries away the calcium hydrate of the cement which is segregated during the setting of the cement mortar. If carbonic acid dissolved in water is added, calcium bicarbonate is formed, which is soluble in water. It can be seen from this that free carbonic acid and water can destroy a thin cement covering over the steel and cause corrosion, but if we consider the small amount of carbonic acid in the air the formation of bicarbonate by the carbonic acid which the air contains seems impossible if the steel is provided with a thin cement coating. The combination of such concentrated rust forming substances as were used in our test will occur very infrequently, and even if they should there would be no danger of rusting so long as the cracks are not large enough to allow the corroding atmosphere to penetrate to the steel, which can only occur after the elastic limit of the steel has been passed.

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* Deutsche Bauzeitung, 1905.

APPENDIX II.

Extracts of reports on tests of slabs reinforced in two directions published in Beton und Eisen, 1909.

The official Prussian regulations require the design of slabs reinforced in two directions to be in accordance with the formula $M = WL^2/12$, while the Hennebique Company build their floors of this type, according to formula $M = WL^2/30$, on the assumption that the edges are partially fixed.

The object of the tests, made by a contractor in Augsborg, Germany, was to show the carrying capacity of slabs reinforced in two directions and to compare the results with the formula.

The first slab was built resting on I beams laid flat on wooden framework and concreted between the flange, the support being arched so as to allow the slab to rock on its bearing in deflecting under load.

The concrete was composed of—

1 part Portland cement,
2 parts washed sand,
3 parts gravel varying in size to $^8/_{10}$ in.
The clear span in direction A = 11 ft. 0 ins.
The clear span in direction B = 9 ft. 9 ins.
Thickness of slab = 3½ ins.
The outside dimensions are 10 ft. 9 ins. x 12 ft. 0 ins.

Reinforcement.—In direction perpendicular to A—31 round bars 3 ins. diameter, spaced from 3½ ins. to 5 ins. on centers.

In the direction perpendicular to B—25 round bars 3 ins. diameter, spaced from 3.9 ins. to 5.9 ins. at the edges.

The crushing strength of concrete at 31 days, 2,300 lbs. per sq. in.

The load was applied in the form of cement bags, short pieces of iron, etc., with the following results:

Loads in lbs. per. sq. ft.	Deflection in ins.
37.5	.0
91.3	.09
145.5	.18
199.0	.37
250.	.60

At this point loading was discontinued for the evening and resumed the next morning. The deflection increased over night to .75 inch, and at this point the first hairline cracks were observed. This loading was continued and at 466 lbs. per sq. ft. numerous cracks appeared in the direction of the diagonals, the largest being about .03 in. wide, the large cracks appearing between the center of the slab and the corners. At this stage the load was partially removed, re-arranged and increased to 688 lbs. per sq. ft., including the weight of the slab, and allowed to remain for two days, at which time the deflection was 2½ ins. and the largest cracks from .04 to .05 ins. wide.

The surface was carefully examined after removal of load for signs of failure in compression, but no evidence was found that the concrete was crushed at any point.

Note.—The resisting moment per ft. of width of slab is 9,650 in. lbs. for 16,000 lbs. per sq. in. in the steel and 11,000 in. lbs. for 650 lbs. per sq. in. in the concrete, consequentily the strength is governed by the tensile strength of the reinforcement. The carrying capacity on the basis of $M = WL^2/12$, $W = 102$ lbs. per sq. ft., and for $M = .62\ WL^2/8$, $W = 110$ lbs. per sq. ft.

The latter results are accordant with Standard No. 4 of this Association, Standard Building Regulations for the Use of Reinforced Concrete, in which the load is distributed in the ratio $r = B^4/(L^4 + B^4)$, giving a factor of safety of about 6.

TEST OF 3 IN. SLAB OVER STAIRWELL.

This test was made by the same contractor as in the case noted above. The slab was partially fixed at three sides by the walls of the stairwell and on the fourth side by a heavy reinforced concrete beam.

The slab was composed of 1 part Portland cement,
1 " washed sand,
1 " gravel.

Thickness of the slab 3 ins.
Clear span direction $A = 9.1$ ft.
" " $B = 9.3$ ft.

Reinforcement.—12 round bars 0.3 in. diameter in each direction, ends bent up and hooked. Between these bars in the middle of the slab, 9 round bars 5.5 ft. long only, but with hooks on the ends same as the bent up bars corresponding to .62 per cent. reinforcement in the middle and one-half that amount near the edges.

The slab was tested 28 days after the concrete was placed, with the following results:

Load in lbs. per sq. ft.	Deflection in ins.
41	0
92	.04
144	.06
195	.11
This load remained one hour without increase in deflection.	
247	.18

After 15 hours this increased to .27 in., at this point the test was stopped because of signs of failure of the supports. No cracks could be found either on the under side nor on the upper surface near the supports where the load had been removed for a short distance to enable observations to be made.

DISCUSSION.

Mr. Talbot.

Mr. Arthur N. Talbot.—Information is desired on tests which have been made on various parts of building construction, particularly of slabs, either as members of a building or separately constructed for the purpose of testing. If such data is of a character to permit the drawing of conclusions, it would be of great value. Surely if such information is not available, this line is one along which the committee may well direct its efforts in securing tests.

Mr. Turner.

Mr. Henry C. Turner.—With reference to the subject of regulations to be adopted by this Association to govern the design of reinforced concrete, in view of the difference of opinion among engineers regarding the proper design of beams, girders and columns, I would suggest that the coming year be spent in further investigations.

At present we have committees recommending $WL/12$ for the positive and negative bending moments of continuous beams and girders, others recommending $WL/10$ for the positive moment with the stipulation that 50 per cent. of the metal shall be bent up over the supports, and still others adhering to $WL/8$. The recommendation of $WL/12$ for the bending moment for continuous beams and girders has the support of the Joint Committee on Concrete and Reinforced Concrete, but many of us are as yet unwilling to make the changes in the construction of beams and girders which would be necessary by the acceptance of the negative moment of $WL/12$.

This subject should be given considerable study by our Committee, and if possible a series of tests made on entire bays to determine the bending moments resulting from continuous action. For this purpose it should be possible to secure the financial assistance of a large number of companies.

Further investigations are also very much to be desired in connection with the safe design of reinforced concrete columns. Very few tests have been made on large columns. I would like

Mr. Turner. to see our Committee direct the construction and design of a fair number of columns both hooped and vertically reinforced. Work of this nature must be done by some association; it is too large for an individual to undertake.

Mr. Lindau. MR. A. E. LINDAU.—I had occasion at one time to test a panel 20 ft. square, with a beam in the middle dividing the panel into two sections of 10 x 20 ft. The slab was 4 ins. thick, with about 7/10 of 1 per cent. of reinforcement in one direction and with one or two transverse bars in the other direction. The floor panels were similar or identical with a floor construction, which was designed for 150 lbs. per sq. ft. floor load. The entire panel was tested to a load of about 800 lbs. per sq. ft. under conditions in which precaution was taken to prevent arch action. The panel was not destroyed. There was a very considerable deflection, about 3/4 of an inch, and cracks showed on the under side of the slab. The panel returned to its original position after removal of the load. In this case the carrying capacity was far in excess of that computed according to the ordinary methods, due to the restraint at the ends, or carrying loads in both directions. This being a type of floor construction in general use, it might be only fair to take into consideration the carrying capacity in the designs, if it is found after careful and scientific tests that we are justified in doing so.

Mr. Perrot. MR. EMILE G. PERROT.—I would like to ask Mr. Lindau if he has looked into the subject of columns, especially hooped columns. The theory of Considére for hooped columns seems to be generally accepted, but I have found no formula for calculating the stress in a hoop and have devised one myself.* If hooped columns are to be used in buildings, the experimental data which has been obtained both in this country and in Europe, should be analyzed and some definite formula derived. Of course, many have made tests, but nearly all have assumed that Considére's theories are proper ones, and adopted that method. I am not so sure that they are right and that there is not some other method of arriving at the hooping stress.

Mr. Talbot. MR. TALBOT.—There is no unanimity of opinion in this matter. Many people still hold that Considére's formula is a cor-

* See p. 346.—ED.

rect one, and possibly it is applicable, so far as the ultimate strength of hooped columns of a limited length is concerned. The opinion advanced by the Joint Committee on Concrete and Reinforced Concrete seems a reasonable one: that hooping is of advantage in giving toughness to the column; that the strength added by the hooping cannot be realized within working stresses; that this added strength is useful as a factor to cover emergencies, accidents and possible poor construction. For these reasons the Joint Committee recommends that where the hooping used was 1 per cent. or more of the volume of the core, a higher working stress should be permitted in the concrete and that no further allowance be made. That is to say, instead of giving a value to the strength of 1 per cent. hooping, the recommendation is that the working stress in the concrete be increased from that for plain concrete, and that nothing be allowed for the hooping itself. The amount of shortening which occurs in a hooped column before its ultimate strength may be utilized is much beyond what would be permissible in building construction; and if we would allow a factor of safety of 2 to 3 on the ultimate strength, the amount of shortening for this load may yet be beyond a permissible amount. **Mr. Talbot.**

One other feature has not generally been taken into consideration, the effect of the length on hooped columns. Ordinary concrete columns have practically the same strength at the upper limit of length as would be obtained with a short column. That is to say, a column of 15 or possibly 20 diameters, reinforced longitudinally, will have within about 10 per cent. of the strength of a short compression piece of 2 or 3 diameters, except as there are more chances of having poor spots in the longer columns. This can be shown analytically and has been shown by tests. With the hooped column, the stiffness of the columns during the time when the hooping is effective, is very small in comparison with the stiffness of plain concrete. The ratio between the additional strength gained by hooping and the additional shortening obtained by the hooping is perhaps only 1/16 as much as what we term the modulus of elasticity of plain concrete. This low ratio results in making the column formula for hooped columns very important, so that with a hooped column of 20 diameters in

Mr. Talbot. length the effect of the hooping, the added strength produced by the hooping beyond the strength of plain concrete, may not be more than—I am speaking from memory now—25 per cent. of that which would be obtained with a hooped column 2 or 3 diameters long—a very great difference. This result has been shown by tests, and an analysis indicates that it is reasonable.

Still another matter about the hooped columns. Many people do not follow the requirements of Considére and the regulations of the French Government, that the pitch of the hooping shall not be more than 1/7 of the diameter of the core. Experiments made on hooped columns with practically the same amount of hooping in all cases, and with pitch of spiral of 1/12, 1/6, 1/4 and 1/3 the diameter, show that when the pitch becomes less than 1/6 of the diameter the hooping is quite ineffective; and for hooping with pitch 1/4 of the diameter there is but very little added strength.

The same information should be applied, it seems to me, when we consider the strength of columns made up of structural steel bars, laced or banded together. The ordinary idea, I believe, is that this lacing or banding sufficiently restrains the concrete to make it act as a hooped column. I do not see how this can be, as these flat bands will first act as beams, and they have very little stiffness, and the volume obtained after these bands bend will be much more than the volume before. It is not to be expected that the lattice bars will bring any hooping effect into action. Tests seem to show that lacing is very ineffective in producing restrained concrete.

Mr. McCullough. MR. ERNEST MCCULLOUGH.—I have noticed a number of columns in which the spiral was very rigidly connected to the upright or longitudinal reinforcement and have wondered if that was not really a detriment. I have been under the impression that the function of the longitudinal reinforcement should be to hold the hooping in place, so as to preserve the pitch. In many of the manufactured columns on the market I have wondered if the effect of rigidly connecting the spiral hooping to the vertical members does not produce a condition very similar to that in banded columns.

The experiments that were made and reported sometime

ago* on concrete reinforced with nails led me to wonder how a column with longitudinal steel in some sort of web, either expanded metal, wire mesh or something of that kind, would act if put in about every 3 or 4 ins. across the column, so that there would be layers† of reinforcement through the concrete. It might have the effect of increasing the strength of concrete very much, as it was increased by the adding of nails. **Mr. McCullough.**

MR. LINDAU.—The only column tests that have been made, to my knowledge, in which the concrete was taken from batches mixed during the construction of a building and handled by workmen engaged in actual construction, showed remarkably good results. The carrying capacity over the entire area of the column averaged about 3,800 lbs. per sq. in. The test columns were made of 1:2:4 limestone concrete about 8 ins. square and 8 ft. long. **Mr. Lindau.**

It has been my practice to use hooped columns only in exceptional cases where the matter of space was of greatest importance, and in others to consider the hooping as an added factor of safety. Hooping is undoubtedly the most efficient form of column reinforcement, but it is a questionable practice to use excessive stresses because of the tendency of the outer layers to flake off.

MR. PERROT.—We have a building where we allow 1,000 lbs. per sq. in. in the concrete and the hooping increases the strength to 12,000 lbs. per sq. in. on the longitudinal reinforcement. They load up to 12 per cent. longitudinally. A six-story building has hooped columns of about 22 in. in diameter, taking the 2 ins. of fireproofing, and the hoops are 17 ins. in diameter. I have collated results of all tests on hooped columns I can find, both in this country and abroad, and on analyzing them I find that the best reinforcement is cement, with hooping second. A 1:1:2 column or a 1:1 plain mortar column, will stand as much as any reinforced column that can be devised with a 1:2:4 mixture. We have compromised on the proposition and use 1 cement, 1 sand and 2 stone for hooped columns, and then add reinforcement to bring the column within reasonable size. **Mr. Perrot.**

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* *Proceedings* Am. Soc. Test. Mats., Vol. IX, p. 514.

† See p. 107.—ED.

Mr. Lindau.

MR. LINDAU.—It is not the intention of the Committee to disregard the tests which have been made on hooped columns and arbitrarily take the stand that the hooping is not a satisfactory form of column reinforcement, but that the present consensus of opinion seems to be against the use of exceedingly high stresses in hooped columns solely because they have an ultimate strength far beyond the ordinary reinforced concrete columns. It is confusing to judge the carrying capacity of columns by noting that columns designed for certain floor loads have stood the test of time and actual use, because it is rarely that columns are called upon to carry their full quota of floor load for all of the floors, and if they do, the total load must be distributed over the entire section of the columns.

If the column is designed for a stress of 1,000 lbs. per sq. in. inside of the hooping, that may mean a stress of not more than 600 lbs. per sq. in. over the total area of the column, if the ordinary rule of using 2 ins. of concrete for fireproofing is followed. At this stress there can, of course, be no evidence of failure.

Mr. Perrot.

MR. PERROT.—Mr. Lindau stated that in figuring a column the fireproofing was included. A plain column is not ordinarily fireproofed to a depth of 2 or 3 ins. If 2 ins. of fireproofing are added to a hooped column, in order to do justice the same thing should be done to the plain column.

The President.

THE PRESIDENT.—In some formulæ a unit stress of 1,000 lbs. in compression is allowed on concrete within the hooping. However, figuring the allowable load that can go on the column within the hooping, as distributed over that entire area of the column, including the fireproofing, the actual load on the column would be within the allowable unit stress for the unreinforced column.

Mr. Lindau.

MR. LINDAU.—The point I wish to make is that within the working stress it would not show any stress on the column. There would be no signs of stress on the surface, therefore, no means of telling whether the column was within the limits of safe practice. I think there is no question of the possibility of designing a column, using a high unit stress inside the hooping, that would show a less cost per lineal foot than a plain column.

But it is a little difficult to say whether the column is overloaded or not without a series of careful measurements of deformation. **Mr. Lindau.**

In designing plain concrete columns the same amount of fireproofing is allowed as in the hooped columns. That is, in designing a plain concrete column, there is added to the area carrying the load 1 or 2 ins. for fireproofing purposes, or the same amount as if the hooped columns were used.

Mr. Perrot. Mr. Perrot.—That is not common practice.

Mr. Lindau. Mr. Lindau.—It is quite common practice throughout the West, which I happen to be more familiar with than with the practice in the East.

Mr. Talbot. Mr. Talbot.—It occurs to me that too frequently in the construction of columns with longitudinal reinforcement, the latter is placed too near the surface of the column. I know that the idea is, that by placing the reinforcement close to the surface of the column there will be an advantage in stiffness, there will be more resistance to flexure, in case tension should ever come upon the column. The chance of tension coming on the side of a column is very remote, particularly in the lower stories of a building. So far as the compressive strength of a column with longitudinal reinforcement is concerned, it seems to me that it is much better to have the rods well distributed over the cross section of the column, rather than have them close to the surface. Surely they ought to be nearer the center of the column than usually placed.

The President. The President.—The question of fireproofing is one on which a great deal of information is needed. Just exactly how much or what should be the character of the protection or the insulation of the loaded members is a problem yet to be solved. I think until we get more definite data on the behavior of the protection in case of fire, we are apt to exact conditions and require things that may not be necessary. The round column seems to offer better resistance to fire, and perhaps not require so much insulation as the square column, where the two faces, submitted to the action of heat, transmit a great deal more heat to the reinforcement. I think it is the duty of our Committee on Fireproofing to crystallize the information available, and then, perhaps, provide us with some definite statement as to what constitutes good fireproofing.

The President. I think Mr. Perrot is correct in his statement that it is not the practice to fireproof a plain column. It is, however, certainly as necessary to protect a plain column as a steel column or any other form of column. If a given area required to carry the load, is figured at a certain unit stress per sq. in., it is manifest that it will not be sufficient in a fire that may reduce the factor of safety to such a low point as to endanger the whole structure. It is, therefore, necessary to provide outside the portion of the column that is to carry the load sufficient concrete to properly insulate the column in case of fire, whether the column be plain or reinforced with metal. Mr. Talbot brought out earlier that one of the advantages of the hooped column is its toughness. While plain columns may be amply sufficient, the failure which may occur under maximum load is very sudden, whereas in a hooped column it is gradual. This is an additional factor of safety.

Mr. Talbot. MR. TALBOT.—I am glad to have a statement favorable to the use of rich, dense concrete for column construction brought out, and I was pleased to hear Mr. Perrot tell about the 1:1:2 mix which he is using. This has long seemed to me as one line along which improvement in building construction might well be made, and that both by using the richer mix and by so choosing the materials as to get dense, strong concrete, our work in column construction may be very much improved. All the tests that have been made and the information that we have about building construction go to show that concrete may be obtained by these methods which will give far stronger and better column construction than is usual.

In the matter of tying longitudinals stiffly to other parts, I think we may not appreciate fully, but we may think at least of the effect of shrinkage of concrete in setting. If we have concrete placed into what becomes a stiff receptacle, as, for example, within a structural steel frame, the effect upon the concrete may be troublesome. We may get a less dense concrete and hence a less strength than we should if the concrete had better opportunity to shrink in every direction.

Mr. Perrot. MR. PERROT.—Referring to the matter of corrosion, we happened to have the very great advantage of tearing down a

building we built four years ago of reinforced concrete. It was a boiler house and engine room with the boilers on the first floor, and, as is unusual, the engines on the top floor, which subjected them to a great deal of stress. The generators and engines, a pair of them, weighing many tons, were on about a 22 ft. square span which was reinforced with metal. In tearing the building down it was necessary to use dynamite, as we could not take it down by any other means. So much dynamite was used that the people in the buildings nearby became so afraid that they threatened to have the contractor arrested if he continued, but he was very nearly done by that time and got along all right. **Mr. Perrot.**

When we examined the steel in the concrete, especially that over the boilers, where sulphurous gases had been arising all the time for four years, we found no evidence of corrosion or bad results from the action of gases, either percolating through the concrete or any other way they might get there. In other words, the building was better the day we tore it down than a year or two before.

TOPICAL DISCUSSION ON CONCRETE AND REINFORCED CONCRETE.

Selection of Materials.

The President. THE PRESIDENT.—One of the most important things that has to do with the use of concrete is the selection of the materials, a matter which receives very little attention. While there are elaborate specifications for cement and for most of the other structural materials, we rarely see a detailed specification relating to concrete. We are rapidly reaching a point where the necessity for stipulating a definite strength for mortar and concrete is becoming imperative. I believe in the next few years we will find in all specifications a requirement fixing a definite strength for the concrete. I believe it is evident that by fixing a compressive strength for the concrete we will in a measure govern the character of all the materials of which it is composed.

The design of a structure must necessarily depend upon the strength of the material of which it is composed. In the design of the concrete structure, it is the practice to assume a compression value of the concrete regardless of whether the material actually used has this strength or not. Only in rare instances is the concrete tested.

The average concrete structure is designed with the factor of safety of 4 and if the strength of the concrete actually used is 1,000 pounds where the assumed strength was 2,000 pounds it is evident that the structure has not a factor of safety of 4 but of 2 only. It would seem, therefore, that it should be the endeavor of the constructor to take every means to insure concrete of that strength being used in a structure that was assumed in its design and the material should be so proportioned and mixed as to secure the requisite strength. This to my mind will be the development of the future and a much more careful study of the materials will be given than has heretofore been our practice.

Mr. Lindau. MR. ALFRED E. LINDAU.—The matter of selection of materials is one of the most important things that we have to consider

in connection with concrete. There is a great deal of information needed regarding materials suitable for concrete and concrete work throughout the country, which information should be available for contractors and engineers interested in concrete. Data as to the effect of various kinds of sands on the cement has not, as far as I know, been published up to this time. **Mr. Lindau.**

The President.—The Chair would say that the question of sand is one of the most important factors in the making of concrete. In the popular sense "sand" is a very indeterminate material and a partial survey of the various sands in this country convinces one that this material has a range of quality so wide that it is evident in framing specifications, the use of the word "sand" without some qualifications which would regulate or control its character, is of very little value. So many things affect the character of the sand that it is almost impossible to enumerate them. The sand may be too fine, the particles too soft, or it may be of one size or it may contain a very large percentage of deleterious matter, and again it may not be well balanced, that is, it may contain a large percentage of either very fine material or of very coarse material. Without the requisite tests it would be almost impossible to determine the proper proportions in which the sand should be used. **The President.**

The proportion in which the material is to be used will depend largely on the strength that is desired for the concrete and this proportion should be so fixed as to secure a maximum density. I believe that the proportion should be stated in terms of maximum density, that is, one part of cement to the total number of parts of aggregates. Just how the materials composing the concrete are to be proportioned necessarily depends on the materials themselves.

The practice of assuming arbitrary proportions, 1:2:4 or 1:3:6, cannot be too severely condemned and we should have specifications requiring a density of 1:6 or 1:9 and then make it the duty of the engineer or contractor to determine the actual proportions of his materials from some simple field tests.

The study of these materials may show that the strength may be greatly increased by washing, that is, by removing the fine or deleterious matter.

The President. It often happens that a well graded river gravel can be used without any admixture of sand or that for stone a run of the crusher requires a very small percentage of sand in order to secure the requisite density. The character of the crushed stone and gravel are so variable and so very largely affected by the quality of the material itself that it is impossible to make any general regulations covering their use. All materials should be studied separately and their proportions fixed so as to secure maximum density.

It often happens that a 1:6 density is required where a very soft aggregate is used, whereas a 1:9 density would be sufficient in the case of a very hard aggregate. We must certainly get into the habit of making density and strength tests in the field and so fix our proportions as to secure the strength assumed in the design of the structure.

Mr. Wiselogel. MR. W. F. WISELOGEL.—If you take any of this Lake Michigan sand that has been blown up in these hills and put it under a microscope, you will find smooth spots, and we have been unable to make a good block with it. The sand should be screened from gravel and have good sharp corners. Of course, coarse gravel or small stone is also necessary so as to fill the voids. I do not believe as dense and strong a concrete can be made with sand, even from the best gravel pit, as with an additional coarse aggregate.

HANDLING OF CONCRETE.

The President. THE PRESIDENT.—The method of handling concrete Mr. Hoff suggested in his paper* is well worth consideration and development. While the method described was made necessary by the conditions yet I believe the necessity for keeping the materials together and preventing the separation of the cement and the aggregate is highly essential; where a chute is used for depositing the concrete it should be kept full so that the material will flow from it in a solid and continuous stream.

This method has been used at St. Louis in the construction of several reinforced concrete buildings and I think is likely to be extensively used. It, however, frequently happens that each

* See p. 180.—ED.

batch of material goes down this chute in such a manner as to **The President.** cause a separation of the cement and aggregate which is extremely objectionable. It would seem that some arrangement should be made by which the chute is kept full during the operation.

Another essential in the use of this method is that the consistency shall be such that the material shall flow readily without being too dry or too wet. Such consistency may be properly described as viscous and can be obtained by a thorough mixing which also insures a better density and therefore a greater strength.

A most careful study of the operation of mixing and placing concrete will, in my judgment, result in a greater density and much better concrete.

Mr. Cloyd M. Chapman.—A concrete storehouse for the **Mr. Chapman.** storage of material in bulk was constructed in Iowa and the walls were built similar to a dam, very heavily reinforced with buttresses. The contractor erected a combination elevator, conveyor and mixer, and a 16 in. screw conveyor, starting far enough from the building so that it reached the proper height when tipped up at an angle of about 30 deg. The stone, sand and cement was delivered by wagon and shoveled into the bottom end of the conveyor, which mixed and delivered the material at the top of the wall. The water was added about 6 or 8 ft. from the discharging end of the conveyor. In order to deliver the mixture at different points on the work there was installed another section of conveyor into which the first conveyor discharged, always adding the water just before the mixture reached the final discharge point. The travel of the mixture was far enough to get a very thorough mix, and the result as shown by some of the completed walls was a beautiful and uniform surface.

Joints Due to Stopping of Work.

Mr. W. F. Wiselogel.—An important point that should **Mr. Wiselogel.** receive consideration is the treatment of joints due to stopping of work. In breaking the concrete at such joints there is always a seam. I noticed in a bridge which was washed out, that wherever they stopped work at night and began the next morning,

Mr. Wiselogel. pieces had spalled off. Possibly if the foundation had not given way the bridge would have been all right, but there always is danger.

Mr. Allen. MR. H. B. ALLEN.—In regard to the stopping of work and allowing concrete to reach hard set before resumption of work, in all sewer construction where the contractors work from day to day, it always has to go on in that way. The concrete often takes a hard set before the work is continued. I think in the experience at Louisville, Ky., with the comprehensive sewer system now underway, that such necessary joints have been found to be very satisfactory.

STANDARD COMPRESSION TEST.

Mr. Chapman. MR. CHAPMAN.—Has anything been done concerning the substitution of the compression test for the tensile test, or requiring a compression test in conjunction with a tension test as a standard test for concrete on construction work? Not for cement, but for mortar and concrete.

The only test now in general use is one of the neat cement and of a mixture of the cement with sand. It is an indicator of the quality of the cement, and is used as an indicator of the quality of the concrete which may be made from that cement. Now we do not use neat cement in construction work very often, but we do use a mixture of cement and aggregates. It is not essential that the resulting concrete, a mixture of the cement and the aggregate, has great tensile strength, because its use in tension is expressly prohibited. Why then should we base our judgment of the compressive strength of a concrete on the tensile strength of a mixture of cement and sand? It is quite conceivable that a concrete may have high compressive strength without a high tensile strength. Suppose, for instance, two beams of equal section and length one of concrete with reinforcing rods longitudinally placed near its bottom, the other built up of metal plates or laminations held together by rods longitudinally placed near its bottom just as in the case of the concrete beam. Now if these two beams are of similar size and shape, with similar rods, similarly placed and so designated that under uniform loading they

shall fail by rupture of the rods in tension, then the strength of these two beams will be about equal. Yet one of them has a strength in tension independent of the rods and the other has none whatever, and as a beam the one without the tensile strength is as effective as the other. Compressive strength is not a function of tensile strength. Then why not require compressive tests of materials to be used in a structure whose safety depends on the strength of those materials in compression. We do not measure light by ascertaining the temperature of the source of the light. Yet in many cases the two qualities are dependent on each other. The light given off by a heated mass is dependent on the temperature of that mass. Yet it is possible to generate light waves without high temperatures. May it not be possible to make a concrete high in that quality which is most necessary to it, namely compressive strength? To that end would it not be wise to specify compressive tests of concrete and to develop a standard form for such tests? I understand that the standard German test, at present, is by compression or by compression and tension. **Mr. Chapman.**

The President.—The Chair would say that the German test for cement is compression. They make no tension test, or at least the standard is a compression test. Our Committee has assumed a compressive strength of 2,000 lbs. per sq. in. for concrete on which to base their unit stresses, and I think the tendency in this country is to study the concrete from its compressive resistance. The only tension tests made at the present time are those for testing cement and in addition to these requirements it is recommended by the various committees, that the mortar from the mixing box shall have a tensile strength of 70 per cent. of that obtained in the laboratory with the same cement and standard sand. There are no specifications in vogue in this country which stipulate the compressive resistance of the concrete. The design of concrete structures is based on the compressive strength and not on the tensile strength. There is no doubt, however, of the great need for compression tests of concrete on the work, and it is probable that such tests will be made more often in the future than is the present practice. Concrete should be subjected to as rigid tests on the work in order to control its quality, as is the **The President.**

The President. present practice with steel. The important structures of concrete now being erected make this practice almost imperative.

Mr. Lindau. MR. ALFRED E. LINDAU.—As I understand the situation it is proposed to substitute a compression test of cement for the tensile test as an indicator of quality. While this may have the advantage of testing the particular physical property we are interested in, were we using neat cement, it is not so certain that it would be a better indicator of the compressive strength of mortar or concrete—the function of the cement being largely that of a binding material. Furthermore, it has the disadvantage of requiring heavier testing machinery.

Mr. Chapman. MR. CHAPMAN.—It is admitted that a great many contractors do now make compressive tests of concretes and mortars. A standard form of compression test should be specified for use on all concrete work where safety depends on compressive strength.

Mr. Anderson. MR. W. P. ANDERSON.—In the Standard Building Regulations for the Use of Reinforced Concrete there is a provision for compression tests,* as follows:

> Concrete composed of materials meeting the requirements of these regulations, mixed in proportion of one part of cement and six parts of aggregate (fine and coarse), shall develop a compressive strength of 2,000 pounds per square inch in 28 days when tested as 8 in. diameter cylinders 16 ins. long under laboratory conditions of manufacture and storage, using the same consistency as is used in the field. When the proportion of cement is increased, using the best quality of aggregates, an increase may be made in all working stresses proportional to the increase in compressive strength at 28 days, as determined by actual tests, but this increase shall not exceed 25 per cent.

I think personally the test may be made or not, because a cylinder of 8 ins. in diameter and 16 ins. long as called for has to be tested in a regular testing laboratory or some place where they have a large machine. Cubes up to 4 ins. square can be tested by the contractor, a small machine costing $100 or so. It is worked by a pressure pump with a pressure gauge. In our work we have one of these machines and make a cube test to see what we are doing. We could not, however, use the large size test piece,

* See page 359.—ED.

but we obtain a good indication as to the relative value of the various mixtures of concrete. **Mr. Anderson.**

The President.—I think Mr. Anderson has shown the practical way of using the compression test to guide the contractor in the field. These particular regulations are devised for municipalities, most of whom have machines that are capable of making tests of this kind. This particular test has been suggested as a standard test, and has the approval of those who have given consideration to the subject. It is quite evident from what Mr. Anderson has said that it is quite practical to obtain a small hydraulic press with a gauge that can be used in the field, and thus enable the contractor to obtain some idea as to the strength of the material he is using. I believe that through the expenditure of a small amount of money, such as Mr. Anderson has indicated, a better quality of concrete is obtainable, because of a more intimate knowledge of the strength as affected by the quality and proportions of the materials, the method of curing and other matters which have an influence on this strength. **The President.**

Mr. Lindau.—Regarding the testing of materials during construction, I would say that in connection with one of the large buildings erected in St. Louis about four years ago, cubes were made and tested at regular intervals to get an idea of the strength of the materials used. These cubes showed at the end of 30 days a compressive strength of 2,000 lbs. per sq. in., and at 60 days about 2,400 lbs. per sq. in. At the same time test columns were made, the concrete being taken from batches mixed during construction. Some of these columns were of plain concrete about 8 ins. square and 8 ft. long; others of the same size were reinforced. After some time they were shipped to the Watertown Arsenal and the results of the tests are very interesting and also very reassuring. A compressive strength from 3,700 to 4,200 lbs. per sq. in. over the total area of the column was obtained, the columns being about two years old at the time of test, thus showing a marked increase in the strength of the concrete since the time the building was erected. **Mr. Lindau.**

Mr. Arthur N. Talbot.—Reference has been made to the tensile strength of concrete as though it were a matter of no importance or of little importance, and we, of course, do appre- **Mr. Talbot.**

Mr. Talbot. ciate that we need dense, strong concrete in order to resist compression. We must not overlook the fact that we want also tensile strength in mortar and concrete. Take even the matter of compression. With the weaker concretes, the tensile strength of the concrete may be an important consideration in its actual compressive strength. When this concrete fails, it bulges laterally, and the real cause of the failure may be the lack of tensile strength. With harder, stronger concrete, the shearing effect is more important. Further, in reinforced concrete beams there is the matter of bond and adhesion. The tensile strength of the concrete has much to do with the properties of the bond between the concrete and the reinforcing metal. In another important matter, however, strength in tension is more striking, and that is, in the kind of failure which ordinarily is termed a shearing or diagonal tension failure, a form of failure which is quite common in beams of considerable depth with respect to their length. The stronger concrete, having the greater tensile strength, is the one which will have a higher resistance against shear failure, and will have a higher strength for beams that are not reinforced for diagonal tension, but which do fail in this way.

It seems to me, therefore, that we should not overlook the importance of the tensile strength of concrete, and that while it may be desirable to have compression tests of mortars, and surely of concretes, the tensile test is still of importance. The method of testing mortars and cements by tension as briquettes I suppose was accepted and adopted because of its convenience, also because there is some general relation between the tensile strength of mortar and its compressive strength. It would be desirable if we could add to the tests of briquettes and of the concrete cylinder which has been mentioned, a further test, that of a short, plain concrete beam, a small test beam, which would give something in regard to the tensile strength of the concrete, and thus tell whether that concrete is made properly to overcome the stresses known as diagonal tension.

Mr. Allen. MR. ALLEN.—Does this requirement of 2,000 lbs. apply in a case where crushed stone or gravel is used?

The President. THE PRESIDENT.—It applies to all kinds of concrete, regardless of the character of the aggregate. Our experiments show

that where washed gravel is used the concrete fails under compressive tests by breaking around the aggregate. When crushed stone is used the failure is frequently through the aggregate. **The President.**

The Chair would further say that while the gravel, usually composed of hard particles, resists the crushing action better than the stone aggregate, in the long time tests the gravel particles fail also in the compression tests.

Mr. Perrot. Mr. Emile G. Perrot.—In the testing of concrete in compression for the purpose of checking up the strength of the building, I would state that our specifications require the contractor to make cubes and we have them tested ourselves. We do not depend on the contractor testing anything. The contractor or the inspector on the work molds the cubes, taking the material directly from a batch leaving the mixer, and the test pieces are sent to the testing laboratory. The city of Philadelphia does the same thing.

The personal equation of the contractor enters largely into the strength of the mixture. Two buildings in the same city within five blocks of one another were being erected and one contractor obtained about 33 per cent. greater structural strength of the concrete than another, both working under the same specifications. The concrete was tested in the same laboratory on the same day, and yet varied 33 per cent., not only in one test but in the majority of them. This shows that one man knew his business and the other did not.

To the consulting engineer the testing is really as important as anything else, and this provision of special regulations for having cubes tested to my mind is not sufficient, because I have found that if concrete has a high compressive strength it naturally has a high tensile strength, if low, the tensile strength will be low. It is largely a matter of getting the concrete up to the standard. We have no trouble with shearing cracks, provided the beam is designed properly. Other considerations, however, enter into the construction of a building outside of the concrete work and the aggregates or materials used. The placing of the reinforcement has a great deal to do with it, the number of stirrups in the beam, the relation of the depth of the beam to its span, are all important things for the engineer to understand. I have seen buildings that

Mr. Perrot. collapsed due to diagonal tension, not that the material was wrong, but that it was placed wrong, giving an insufficient number of stirrups to the beam. Test the same concrete as a cube and you will find that it comes up to the requirements of the specifications. The workmen did not put the concrete in properly and the stirrups were not correctly distributed. Other conditions also entered into the failure, and the beam had to be taken out. So it is not merely testing that is necessary to secure safe work.

Mr. Larned. MR. E. S. LARNED.—Where a comparison of tensile with compression tests is desired, it is essential that the test pieces be made from the same materials, sand and cement, and from the same batch. Frequently, comparison is drawn between tensile tests for which the materials are prepared in the laboratory and compression tests for which samples are taken in the field. It is obvious that these tests are not comparable, due to the difference in the amount of water used, method and thoroughness of mixing, and often, and of even greater importance, a difference in the character and quality of sand.

The requirement that commercial sand shall show at least 70 per cent. of the results obtained in the use of the Standard Ottawa Sand with the same cement, is a most important and timely one, but where, as in this case, the mortar made of commercial sand is to be taken from the mortar box, in the field, the above conditions affecting the comparison should not be overlooked. In ordinary concrete operations, we do not have the so-called mortar box, but it is entirely possible to obtain, from mixed concrete, samples for test purposes representing what could be called the mortar, but it is of an entirely different consistency usually from the specimen prepared in the laboratory, either with the same sand, or in the usual tests using Ottawa sand. These conditions not only affect the comparison of tensile results, but also the comparison between tests for tension and compression, unless all test specimens be made from the same mortar.

The ratio between the tensile and compressive strength is not the same for all periods of time, nor for all proportions or consistencies of mixture, and it is important to observe this distinction in drawing comparisons.

Mr. H. P. Converse.—I would like to ask Mr. Perrot in what respect, in his judgment, the one contractor did not know his business and the other did. **Mr. Converse.**

Mr. Perrot.—One of the contractors was an experienced man, having constructed a number of buildings of reinforced concrete, and the other was a carpenter contractor who was experimenting on his first building. He had a mechanical batch mixer, operated with an engine; the two buildings were very similar in design. I think that the materials were practically the same and came from the same locality, but the mixing and placing had a great deal to do with it, one man being more experienced than the other. It was very hard to judge where the trouble was. **Mr. Perrot.**

Mr. Lindau.—In connection with the variation in strength of concrete due to handling, I would suggest that this may be due not only to a difference in the mixing but perhaps more to the handling of the concrete after it has been mixed. If the proportions, the approximate time of mixing and the amount of water used in the two cases were the same, and the cement had been tested to show that it was the same quality in both cases, it would seem that the difference between the results obtained must be due to the handling of the concrete after it left the mixer. One man will tamp his concrete, work out the air bubbles and make the concrete dense and compact and naturally there results a strong concrete. The other man will throw the concrete in, have too much water in it, in which case the mortar frequently separates from the aggregate, and the result is a porous, non-homogeneous and poor piece of concrete. **Mr. Lindau.**

Mr. Perrot.—I think the placing of the concrete has a great deal to do with it. It was not parts of the building that were tested, but cubes made on the job, so they ought to be nearly the same. **Mr. Perrot.**

We also made load tests on the floors after the two buildings were finished, and a panel made of the poor concrete stood up as well in the floor as panels of the concrete which was supposed to be better. So in the actual building we could not see much difference, while the tests did show a great deal of difference.

The President.—The Chair is of the opinion that the testing of the concrete on the work is not necessarily a matter for **The President.**

The President. the contractor to be solely interested in, but it is a matter for the architect or the engineer. Representatives of the engineer or architect should make the cubes or other test pieces; because after all the responsibility rests on the man who designs the building as well as on the contractor.

Now the mere testing of materials that go into the building in the form of a cube will not insure a perfect building. You must have first-class concrete to begin with. This is essential, but you must equally have first-class workmanship.

The Chair would call attention to a series of tests which have not yet been published, forming a part of a comprehensive study of concrete beams, and made in order to obtain some data as to the effect of workmanship. Three responsible contracting firms in the city of St. Louis were invited to bring their most experienced men to the laboratories, and make up a series of beams, cylinders and cubes. The materials and all necessary tools and apparatus were supplied, and the only thing the men had to do was to take the materials, mix the concrete and place it in the molds. It was an astonishing fact that the compressive strength of the concrete made of the same materials, each foreman trying to do what he thought would be the best piece of work, showed a range of considerably over 100 per cent., demonstrating that after all there is a good deal in the mixing.

It was also notable in these tests that where the concrete was mixed by hand, the variation was much greater than where it was mixed by machinery. The contractors made a series in which they used a batch mixer; some beams were made and stored in the open air, being exposed to weather, and others were made in a room being kept damp during the period of curing. It was quite evident from the tests that the workmanship, the amount of work done on that concrete, was a most important factor in determining the actual strength of the concrete. This is one of the subjects that has been touched upon only slightly, and the tests show that it is absolutely essential that the mixing be most thorough and complete. There is a tendency to use a large percentage of water in order to shorten the time and reduce the labor of mixing. One of the essential conditions for

securing good concrete is that the materials shall be mixed together in the mixer for at least a minute and a half. You cannot tell from the appearance of concrete that looks homogeneous that it is thoroughly mixed. You must rub these materials of concrete together to secure a dense and well mixed concrete. There is a tendency to rush it out of the mixer too soon, and the advantage of thorough mixing is apparent in a good many ways. Since less water is required in mixing, the concrete will usually harden quickly so as to permit the removal of the forms in less time. There will also be a greater strength, resulting from the use of a smaller percentage of water and from working out the air, thereby securing a greater density. **The President.**

MR. TALBOT.—The making of concrete would be greatly improved if more pains were taken to secure a balanced aggregate. It is not necessary to use elaborate tests to determine the proper mixture. If the materials are measured and mixed in different proportions and the weight of a bucketful or cubic foot of the several mixtures be taken, it would nearly be true that the mixture having the greater weight and therefore the greatest density, would also have a greater strength than the other mixtures. This method of experimenting is not a complex one, and is not particularly a laboratory method. It is a method by which anyone can determine what combination of sand and broken stone, or sand and gravel, will give the greatest density. **Mr. Talbot.**

MR. RUDOLPH P. MILLER.—How does the strength obtained compare with material prepared in the laboratory in the same manner, at 2,000 lbs. **Mr. Miller.**

THE PRESIDENT.—In those particular tests the mix was 1:3:6. The laboratory made at the same time a parallel set of tests with their squad of men, which tests showed a strength of approximately equal to the maximum. I think they were a trifle higher than the maximum. **The President.**

MR. MILLER.—On several occasions I have taken specimens for test purposes from completed structures and have, in all cases, found that the concrete showed much less, in fact, in most cases one-half of the strength that it was supposed to have. With the mixtures as given in the specifications it should have developed a compressive strength of about 2,000 lbs. per sq. in., but showed only about 1,100 lbs. This proves that the workmanship is very **Mr. Miller.**

Mr. Miller.

important and unless thorough mixing, thorough workmanship and careful proportioning of the materials are obtained the results will not be satisfactory. In one instance the material was at fault rather than the workmanship. In this case the gravel which was used in the concrete was not as clean as it ought to have been. It was unwashed river gravel.

The President.

THE PRESIDENT.—The only supervision the tests had was by the laboratory assistants who made a record of the method of procedure, and measured the amount of water used. The water was measured in buckets and the foreman in charge of the construction squad stipulated how much water he wanted. But aside from that no instructions were given to the foremen in charge of the squad of laborers. That is, the concrete was prepared by a gang of men who were brought from a building in actual construction for the purpose of making up this series of beams. It took two days to complete the molding of the beams. There was some criticism of the tests on the ground that the mixture was too lean. That is, it was not good practice to use a 1 : 9 density, but this mixture was of 1 : 6 density usually, and the series was subsequently repeated using a richer mixture. With a richer mixture the difference in strength was not nearly as great, although there was still some discrepancy between the three squads. I think we can reasonably assume, therefore, that the increase in the percentage of cement tends to equalize the irregularities due to mixing.

The beams were 8 x 11 ins. in section, 13 ft. long, and at the same time a cylinder 8 ins. in diameter and 16 ins. long, also a 6 in. cube were made. I would add further that the beams were designed to fail in compression; that is, so the concrete would fail in compression. In order to determine the character of the concrete used in the beams, cylinders and cubes were also made of the same material that went into the beams, and enough material was mixed at one time to mold three beams.

Mr. Perrot.

MR. PERROT.—In regard to a rich mixture of concrete, it was the practice in Philadelphia, about eight years ago, to use a 1 : 2½ : 5 mixture; but the building regulations now specify 1 : 2 : 4. It was considered that with the growing demand for concrete, everybody was going into the business, and to offset possible poor workmanship the richer mix was required, thinking

that if poor workmanship entered into the building the cement might help to counteract that bad feature. If you have a richer mix you are almost sure to get somewhere near an average concrete. **Mr. Perrot.**

Buildings of the 1:2½:5 mixture showed wonderful strength. They were structures carefully built by specialists who had learned the business in Europe and who did not use a sloppy mix. I remember my first experience, when at St. Paul I saw such concrete used as made it appear as if they were constructing cream instead of concrete buildings. Whereas the work done in Philadelphia and Baltimore, also by men who had worked in Europe, necessitated ramming the concrete. The amount of water has a good deal to do with the strength and I think too much is used, the tendency now being towards a poured building, because it is difficult to keep the rods in position when ramming concrete. I remember one building erected by a foreign concern where someone had to hold the stirrups while another rammed the concrete.

MR. CHAPMAN.—I would like to ask if Mr. Perrot can describe how wet he thinks concrete should be. Is there any way of telling when you have the right consistency? **Mr. Chapman.**

MR. PERROT.—If the concrete quakes I should say it was pretty wet. Good practice demands that the materials must not separate, when taken from the mixer to the place of deposit. In other words, the stones must not settle to the bottom and the finer materials come to the top. **Mr. Perrot.**

In an eight-story building where the concrete was mixed too wet, when the day's work was stopped the water and finer materials ran under the dams into the portion to be concreted the next day. This material has separated from the concrete poured the next day and has fallen off, making the beam look as though it were breaking apart. In one case a section about 6 ft. long, tapering from 1½ ins. thick to nothing, fell right down on a work bench. The fine particles, laitance and so on, which separate from the concrete, have a different coefficient of expansion from the main body, and when the building dries out after a year or so, you have those particles coming off. That is the result of the concrete being too wet.

The President. THE PRESIDENT.—I think one of the important features of concrete is the question of consistency. If you are not going to work your materials you will have to use water. The danger in using water is that the aggregates are likely to separate. The essential thing is that the concrete shall be homogeneous, and the best way to get a homogeneous condition is to use as little water as will make a concrete so plastic that it will flow readily and will have to be pounded to be compacted in the forms and around the reinforcement. A well made concrete has simply to be sliced a trifle to make it flow around the reinforcement. As far as the conditions in Europe are concerned, I think from personal observation, that there are the same extremes of practice as there are in this country. You will see concrete so dry that the whole structure vibrates under the pounding; and again, you can find it so wet that the cement is running off through the forms. I think that as far as the workmanship is concerned, the same difficulties will be found in all parts of the world.

One of the good influences resulting from the poured house proposition to which a great deal of notoriety has been given, is the tendency to use a better consistency in the concrete. I understand that the idea of Mr. Edison in pouring such a house is to have the concrete of a consistency that can be poured in an orifice, about the way iron is cast, and to pour the house at one operation, remove the forms and have a completed building. In the execution of that work Mr. Edison has encountered some trouble, as would be expected. If you can imagine a room with beams, columns and reinforcement, you can imagine that it will be a difficult thing to get a concrete that will flow through all parts of that form alike so as to secure a homogeneous structure. One of the essentials he has found is that a fine aggregate must be used, that is, the maximum size of the coarse aggregate must be perhaps no more than ⅜ of an inch. To a certain extent this is the tendency in Europe, as with that size of aggregate a homogeneous mixture can be more readily obtained than with larger aggregate. Mr. Edison has been trying to increase the viscosity of his concrete. A viscous liquid is one that sticks together well, at the same time flows sluggishly, about the same way molasses flows in the winter. I think we must secure a material so viscous that

will flow and at the same time hold the aggregates together. **The President.** Such a mixture does not need pounding to be compacted, but simply slicing to get the material to flow around the reinforcement and into all portions of the forms. Such a consistency is what we must strive to attain, for it is one which will give the best satisfaction.

MR. WALTER F. BALLINGER.—What is the effect of wetting **Mr. Ballinger.** concrete once or twice a day in warm weather about a week after it is cast. I mean the difference in the resulting strength of the concrete. We require it to be wet and believe that we get a greater strength by wetting it than otherwise.

THE PRESIDENT.—The Chair would say that the most prac- **The President.** tical answer he can give to that question is reference to tests where beams were made in the open air, exposed freely to the atmospheric conditions, and also similar beams made by the same force of men, placed in a room in which they were kept damp. No particular difference in the strength of the concrete was noted. I think, however, that a practical condition is involved in that the exposed beams had wooden forms around them, which gave some protection. A very thin structure may dry out too quickly. On the other hand, I do believe that if the concrete is properly made at the time and the member is reasonably thick, that while the surface may dry out the interior will still have sufficient moisture to enable the concrete to properly harden. The great trouble is the rapid evaporation of the water in concrete during the early stages. For instance, where materials lie in the sun and are thoroughly heated, and then used in concrete there is a tendency for the moisture to dry out before the concrete can be placed in the forms. As a consequence, the concrete is so dry that the hardening is either retarded or checked.

MR. WISELOGEL.—I would like to ask whether in using **Mr. Wiselogel.** a soft mixture it is liable to separate in spading, or does it go back to a homogeneous mass. In building a pier and simply dumping the concrete in and a man is spading along the edges of the form, does that not overcome the separation?

THE PRESIDENT.—One of the difficulties in placing material **The President.** in layers is that when a man walks on the layers or tamps too much, there is a tendency to drive the coarse aggregates down

The President. and bring up the finer materials, causing the formation of laitance on the surface. This creamy material hardens very slowly, and the deposition of concrete on top of this laitance leaves a weak seam in the structure. Many cracks which develop are in part due wholly to that cause.

In the matter of patching, it is good practice to clean off all this soft fine material, using preferably a wire brush, in order to produce a thoroughly clean surface to secure a good contact between the old and the new concrete. In depositing concrete, all that is necessary to get a smooth finish is perhaps to slice along the form. With reinforcement it is only necessary to slice sufficiently to get the concrete to flow around the reinforcement. In my judgment, as little work as you can do to get concrete, of the proper consistency, into place, the better it is going to be for the homogeneousness of the entire structure.

Mr. Chapman. MR. CHAPMAN.—In order to leave the surface in such condition that work may be continued on the following day or at any subsequent time, the surface can be raked over with an ordinary steel garden rake after the concrete has taken its initial set and before the final set, so as to break up the cream and leave a very rough surface. Before continuing work the next day the surface should be cleaned with a stiff broom or washed off with water under pressure from a hose. This will leave a very rough surface to which the new work will strongly adhere.

REPORT OF THE COMMITTEE

ON

BUILDING LAWS AND INSURANCE.

PART I. BUILDING LAWS.

The Committee on Building Laws and Insurance submits herewith revised Proposed Standard Building Regulations for the Use of Reinforced Concrete,* for discussion and adoption. The Committee also presents a tabulation of the building code requirements (see Plate V, opposite p. 344) of the principal cities of this country so as to afford a comparison with the proposed Standard Regulations.

For the purpose of inviting discussion on the question of hooped columns the Committee appends excerpts from the building laws of Chicago, St. Louis and Cincinnati, and a discussion on the subject by Mr. Emile G. Perrot. The matter is not recommended by the Committee as a whole for adoption as part of the Standard Building Regulations, but is submitted at this time for the purpose of securing suggestions by means of discussion which may be of service to the Committee.

The collation of insurance rates is submitted as Part II of this report.

WM. H. HAM, *Chairman.*
EDWARD D. BOYER.
JOHN E. CONZELMAN.
H. S. DOYLE.
EMILE G. PERROT.

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* The Standard Building Regulations for the Use of Reinforced Concrete as adopted appear on pp. 349-361.—ED.

APPENDIX.

REGULATIONS REGARDING HOOPED COLUMNS FROM ST. LOUIS BUILDING LAWS.

If a concrete column is hooped with steel near its outer surface either in the shape of circular hoops, or of a helical cylinder, and if the minimum distance apart of the hoops or the pitch of the helix does not exceed one-tenth the diameter of the column, then the strength of such column may be assumed to be the sum of the following three elements: *First,* the compressive resistance of the concrete when stressed not to exceed five hundred pounds per square inch, for the concrete inclosed by the hooping, the remainder being neglected. *Second,* the compressive resistance of the longitudinal steel reinforcement when stress does not exceed allowable working stress for steel in tension. *Third,* the compression resistance which would have been produced by imaginary longitudinals, stressed the same as the actual longitudinals, the volume of the imaginary longitudinals being taken at two and four-tenths times the volume of the hooping. In computing the volume of the hooping it shall be assumed that the section of the hooping throughout is the same as its least section. If the hooping is spliced the splice shall develop the full strength of the least section of the hooping.

REGULATIONS REGARDING HOOPED COLUMNS FROM CHICAGO BUILDING LAWS.

(In operation, but not formally adopted.)

536. Ratio of moduli of elasticity. The calculations for the strength of reinforced concrete shall be based on the assumed ultimate compressive strength per square inch given in the table below for the mixture to be used.

The ratio of the modulus of elasticity of steel to that of the different grades of concrete shall be taken in accordance with this table:

Mixture.	Ultimate Compressive Strength per Sq. In.	Ratio of Moduli.
1 : 1 : 2	2,900	10
1 : 1½ : 3	2,400	12
1 : 2 : 4	2,000	15
1 : 2½ : 5	1,750	18
1 : 3 : 6	1,500	20

544. When the reinforcing consists of vertical bars and spiral hooping, the concrete may be stressed to ¼ of its ultimate strength as given in table (536): provided that the amount of vertical reinforcing be not less

			Before 1907. New York, Borough of Manhattan.	Before 1907. Borough of Brooklyn.	May 1, 1909. Buffalo, N. Y.	1907. Boston, Mass.	1908. Chicago, Ill.	Denver, Col.	Louisville, Ky. (Old Code.)
Cement.	Kind		Portland.	Portland.	Portland.	Portland.	Portland.	Portland.	Portland.
	Tensile Strength (neat) 24 hours	Lbs. per sq. in.	120	175	...	150 to 200	200	200	...
	7 days	"	300	500	500	450 to 500	500	500	...
	28 days	"	...	600	600	550 to 650	600	600	...
	Fineness, constancy of volume, etc.	...	A. S. C. E.	Special rules	A. S. C. E.	A. S. T. M.	A S. T. M.	A. S. C. E.	A. S. T. M.
Concrete.	Proportions	Parts by volume	1–2–4	1–2–5 1–2–4	...	1–5 ‡	See note 1	1–2–3	1–2–4
	Consistency	...	Wet	Wet	Wet	...	Wet	Wet	...
	Size of Stone. Foundations	Ins.	¾	2	¾	...	2	2	2
	Columns	"	¾	2	¾	...	2	2	1½
	Slabs	"	¾	¾	¾	...	...	¾	1
	Strength. Compression 28 days	Lbs. per sq. in.	2,000	2,000	2,000	2,000	See note 1	...	...
	Allowable Stresses. Tension	"	None	None	None	None	...	None	None
	Shear	"	50	75	50	60	...	50	30
	Bond	"	50	75	50	60	50–70–80	75	30
	Compression. Direct	"	350	400	350	350 †	...	450	700
	Extreme Fibre	"	500	500	500	500 to 600	...	500	700
Reinforcement.	Tensile Stress	"	16,000	16,000	16,000	16,000	⅓ elastic limit, but not over 18,000	⅓ elastic limit	12,000 to 18,000
	Shearing Stress	"	10,000	10,000	10,000	10,000	12,000	10,000	10,000
	Ratio of Moduli of Elasticity	...	$\frac{1}{12}$	$\frac{1}{12}$	$\frac{1}{12}$	Beams, Slabs } $\frac{1}{15}$ Cols. $\frac{1}{10}$	See note 1	$\frac{1}{15}$	...
Columns.	Stresses with Horizontal hooping	Lbs. per sq. in.	...	600–750	...	...	⅕ ultimate	...	...
	Spiral hooping	"	Special formula	1,000c 6,000s	...	...	¼ ultimate Note 1	...	...
	Ratio of height to least diameter	"	$\frac{1}{12}$	$\frac{1}{13}$	$\frac{1}{16}$	...	$\frac{1}{12}$	$\frac{1}{15}$	...
	Spacing of ties	Ins.	Least width of col.	1½x least width column	Least width of col.	...	12x dia. of rods, and not over 18 in.	Least width of col.	...
	Minimum percentage of reinforcement	...	...	$\frac{1}{200}$	...	...	$\frac{1}{200}$ Note 2	...	...
Slabs.	Minimum thickness	Ins.	3½	3½ in.	3½*	...	...	...	...
	Width allowable in figuring Tee beams	...	10x width of beam.	10x width of beam	10x width of beam	¼ span of beam	Special rule Note 3	5x width of girder	...
	Deflection allowed on load test	Ins.	3x load no sign of failure	Twice load $\frac{1}{700}$ deflection	3x lo d no sign of failure	$\frac{1}{360}$ span	Twice L. L., no failure	Twice load $\frac{1}{700}$ deflection	...
Beams.	Maximum percentage of reinforcement	...	...	...	...	...	...	...	...
Bending Moments.	Beams	...	$\frac{WL}{8}$	$\frac{WL}{8}$	$\frac{WL}{8}$	Contin. $\frac{WL}{10}$	$\frac{WL}{10}$ and $\frac{WL}{12}$	$\frac{WL}{8}$	...
	Slabs. Continuous	...	$\frac{WL}{10}$	$\frac{WL}{10}$	$\frac{WL}{10}$	$\frac{WL}{10}$	$\frac{WL}{10}$ and $\frac{WL}{12}$	$\frac{WL}{12}$	...
	Supported on all four sides	...	$\frac{WL}{20}$	$\frac{WL}{20}$	$\frac{WL}{20}$	...	...	$\frac{WL}{20}$	...
Insulation.	Columns	Ins.	2*	2	2*	1½	1½	1½	2
	Beams	"	1½*	1½x dia. of bars 1½ in. min.	1½*	1½	1½	1¼	...
	Slabs	"	1*	1½x dia. of bars 1½ in. min.	1*	¾	1½ min.	½	...
	Walls	"	...	Not less than 1 in.	1½*	...	...	...	...
Centering; time for removal.	Columns	...	Variable	Variable.	...	...	4 days	4 days	10 to 15 days
	Beams	...	Variable	Variable.	...	...	14 days	12 days	14 to 21 days
	Slabs	...	Variable	Variable.	...	...	7 days	6 days	10 to 15 days

* Rulings not set forth in code.
† Not enforced.
‡ Fine and coarse aggregate.
§ Hooping to be approved.
‖ Depending on weather.

** Add 25 per cent. with richer mixture.
†† See §67.
‡‡ Depends on weather.
§§ Artificial heat.

NOTE 1.

Mix.	Ratio.	Ult. Comp.
1:1:2	10	2900
1:1½:3	12	2400
1:2:4	15	2000
1:2½:5	18	1750
1:3:6	20	1500

AL CITIES OF THE UNITED STATES.

Before 1909. Philadelphia, Pa.	Pittsburgh, Pa	April 1, 1907. St. Louis, Mo.	Baltimore, Md.	May 10, 1909. Cincinnati, Ohio.	Royal Institute of British Architects.	National Fire Protection Association.	September, 1909. Cleveland, Ohio.	Rochester, N. Y. No code but following allowed.	Seattle, Wash.	Standard Building Regulations of National Association of Cement Users.
Portland.	Portland.	Portland.	Portland.	Portland.	Portland.	Portland.	Portland.	Portland.	Portland.	Portland.
175	200	200	....	150–200	....	300	200	....	....	100 to 200
500	500	500	....	450–550	....	500	500	....	300	450 to 550
600	600	600	....	550–650	....	600	600	....	400	550 to 650
A. S. C. E.	A. S. C. E.	A. S. T. M. A. S. C. E.	....	A. S. T. M.	....	A. S. C.E.	A. C. S. E.	....	A. S. C. E.	A. S. T. M.
1-2-4	1-2-4	1-2-4	1-2-4....400 1-2-5....350	1-2½-5 min.	....	1-3-5	1-2-4	1-2-4	1-2-4	1 to 6 of fine and coarse
Wet	Wet	Wet	Wet	....	....	Wet	Wet	....	Wet	Medium wet
2	2	2	2	....	¾	¾	2	....	....	....
¾	¾	¾	....	....	¾	¾	¾	....	¾ to ¼	1¼ ring
¾	¾	¾	1	....	¾	¾	....	....	....	1½ ring
2,000	2,000	2,000	2,000	....	2,400	2,000	2000	....	....	1 to 6—2,000
None	None	None	None	None	None	None	None	....	None	None
75	50	25	50	65	60	50	50	....	50	40
50	50	50–30	60	....	100	50	....	....	75	80 to 150
500	500	500	500	1-2½-5....500 1-2-4....600 1-1½-3....700	500	350	500	750	*350–400	450 to 650**
600	600	800	....	1-2½-5....600 1-2-4....700 1-1½-3....800	600	500	700	750	500–600	650**
16,000	16,000	14,000 20,000	16,000	16,000 to 20,000	15,000 to 17,000	¼ of ultimate strength	16,000 and 20,000	20,000	⅓ elastic limit, but not over 20,000	16,000 to 20,000
10,000	10,000	10,000	10,000	10,000	....	10,000	10,000	....	10,000	10,000
$\frac{1}{12}$	$\frac{1}{12}$	$\frac{1}{15}$	$\frac{1}{15}$	Note 4	$\frac{1}{15}$	$\frac{1}{18}$	$\frac{1}{15}$	....	$\frac{1}{15}$	$\frac{1}{15}$
500	6,000 S. 600 C.	7,500 S. 500 C.	600c	Special rule	....	6,000s 350c	400 and 500	750	450	450 to 562**
§ 7,500 S. 1,000 C.	Special formula	Special rule	....	Special rule	....	....	....	....	*800	1% hooping–650c** 1–4% vert. 9750s
$\frac{1}{15}$	$\frac{1}{15}$	$\frac{1}{15}$	$\frac{1}{16}$	$\frac{1}{18}$ Note 5	....	$\frac{1}{12}$	$\frac{1}{12}$	....	$\frac{1}{15}$	$\frac{1}{15}$
§ Least width of col.	Least width of col.	20x least width of longitudinal member	12	$\frac{1}{16}$ sq. in. at 12 in.	....	Least dia. of col.	12	12	Least diam. of col. not more than 12 in.	....
....	....	1 per cent.	....	....	....	....	....	....	....	1–4% allowed
....	....	....	4	3	....	....	4	....	....	....
20x thickness of slab	10x width of beam	¼ span of beam	....	Beams full slab; Girders { 6x thickness of slab on each side	⅓ span of beam	....	....	....	*5x thck. of slab and breadth of beam	⅙ span or 6x thickness of slab each side
....	....	....	2x LL with no sign of cracks	....		....	3x LL, no failure	....	2x LL. Def. .00143 of span	....
....	....	....	Straight line formula 1%	....		....	....	....	....	....
$\frac{WL}{8}$	$\frac{WL}{8}$	$\frac{WL}{8}$	$\frac{WL}{10}$	$\frac{WL}{8}$ Simple 80% if cont.	$\frac{WL}{8}$	$\frac{WL}{8}$	$\frac{WL}{8}$ x $\frac{WL}{10}$	....	$\frac{WL}{8}$	$\frac{WL}{8}$ $\frac{WL}{10}$ $\frac{WL}{12}$
$\frac{WL}{10}$	$\frac{WL}{10}$	$\frac{WL}{12}$	$\frac{WL}{10}$	$\frac{WL}{10}$ or $\frac{WL}{12}$	$\frac{WL}{12}$	$\frac{WL}{10}$	$\frac{WL}{10}$	$\frac{WL}{10}$	$\frac{WL}{12}$	$\frac{WL}{12}$
$\frac{WL}{20}$	$\frac{WL}{20}$	$\frac{WL}{24}$	....	Special rule	....	$\frac{WL}{20}$	Special rule	....	$\frac{WL}{20}$	$\frac{WL}{12}$ each way
2	2	2	1½	1	2	4x dia. of bar to 4 in.	2	....	1½	2
2 on bottom, 1½ on sides	1½	1½	1	1	1½	4x dia. of bar to 4 in.	1½	....	1½	1½
1	1	1	½	½	1	1	¾	....	½	1
1½	1½	1½	....	....	1	....	....	....	....	....
Not less than 4 days	....	‖ 10 days	....	....	8 to 28 days	1 to 60 days	....	....	12 days	4 or more days‡‡
Not less than 2 weeks	....	‖ 10 days	....	....	Depending on weather condit'ns	Depending on weather condit'ns.	....	....	12 days	10 days‡‡
Not less than 1 week	....	‖ 4 days	....	....			....	....	12 days	7 days‡‡

NOTE 3.

Limit of S $\left(1-\frac{S^2}{L^2}\right)$

or $\frac{L}{3}$ or ⅔ S

L = Clear span of ribs.
S = Full span of slabs.

NOTE 4.

Comp.	Ratio.
500	20
600	18
700	15
800	12

NOTE 5.

Length. / Least dimens.	Per. cent. of steel.	Per cent. of allowable stress to be used for value of Concrete in Comp.
18–20	1½	90
20–22	1½	79
22–24	1¾	67
24–26	2	54
26–28	2¼	41
28–30	2¾	27
30–32	3	12

than the amount of the spiral reinforcing, nor greater than five (5) per cent. of the area within the hooping; that the percentage of spiral hooping be not less than one-half of one per cent., nor greater than 1½ per cent.; that the pitch of the spiral hooping be uniform and not greater than 1/10 of the diameter of the column, nor greater than 3″; that the spiral be secured to the verticals at every intersection in such a manner as to insure the maintaining of its form and position; that the verticals be spaced so that their distance apart, measured on the circumference be not greater than 9″ nor ⅛ the circumference of the column within the hooping. In such columns the action of the hooping may be assumed to increase the resistance of the concrete equivalent to 2½ times the amount of the spiral hooping figured as vertical reinforcement. No part of the concrete outside of the hooping shall be considered as a part of the effective column section.

REGULATIONS REGARDING HOOPED COLUMNS FROM CINCINNATI BUILDING LAWS.

(*e*) The ratio of modulus of elasticity of steel to that of concrete shall be taken in accordance with the following table:

Working Strength of Concrete.	Ratio of Modulus of Elasticity of Steel to Modulus of Elasticity of Concrete.
500	20
600	18
700	15
800	12

Section 4. Design.—Spiral hooped columns shall be hooped with spiral hoops firmly secured against displacement during construction, to not less than six (6) vertical steel members, having a minimum total area in cross section of one (1) per cent. of the area of the concrete. The hoops shall be placed not more than one and three-quarter (1¾) inches apart and the ends hooked six (6) inches into the column; splices must be made in such a manner as to develop the full strength of the hoops. Wherever the hoops are forced apart or spaced further than the figured distance, auxiliary reinforcement shall be provided so as to maintain the full strength of the column.

Spiral hooped columns shall be figured as follows:

Total stress = [A—I—R (S—I—2.2 H)] C.

A = area inside of hoops.

R = ratio of moduli of steel to concrete.

C = allowable value of reinforced concrete in direct compression.

S = area of vertical steel.

H = area of a bar of steel one foot long equal in weight to the hooping steel in one foot length of column.

In all cases, reinforced columns must contain at least one (1) per cent. of vertical steel, and must in all cases have a positive means of confining the concrete and steel either by spiral reinforcement or hoops encasing the vertical bars.

DISCUSSION* BY EMILE PERROT.

While it has been the custom to calculate the strength of columns reinforced with longitudinal bars only laced together, by the formula based on the moduli of elasticity of the two materials and the area of each material, very little has been accomplished in the deduction of a practical working formula for hooped columns with longitudinal reinforcement.

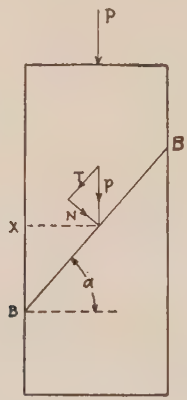

FIG. 1.

Considére's theory, which is used as a basis for calculating hooped columns, is as follows:

The compressive resistance of a hooped member exceeds the sum of the following three elements:

1. The compressive resistance of the concrete alone.

2. The compressive resistance of the longitudinal bars stressed to their elastic limit.

3. The compressive resistance which would have been produced by imaginary longitudinals at the elastic limit of the hooping metal, the volume of the imaginary longitudinal being taken at 2.4 times that of the hooping.

* Originally submitted to the Engineers' Club of Philadelphia

In deducing a formula based on the above assumptions, it is necessary to take into consideration the bursting pressure or lateral tension, due to the spreading or bulging of the columns near the center when compressed. This can best be understood by the following illustrations:

If a prism of concrete be loaded as shown in Fig. 1, the prism may shear off diagonally, if loaded to destruction, instead of failing by direct compression of the material, since the tensile strength of concrete is much less than its compressive resistance. To ascertain this shearing stress, we may reason as follows:

Let the sectional area of the prism = A, then the unit stress on the cross-section $S = \frac{P}{A}$, and the stress on the oblique section B. B, making an angle a with the cross-section, may be found thus: Resolve P into components, normal N = P cos a and tangential T = P sin a.

The area of the oblique section $BB = A_1 = \frac{A}{\cos a}$.

The normal stress $= \frac{N}{A_1} = \frac{P \cos a}{\frac{A}{\cos a}} = \frac{P \cos^2 a}{A}$.

Tangential or shearing stress

$$= \frac{T}{A_1} = \frac{P \sin a}{\frac{A}{\cos a}} = \frac{P \cos a \sin a}{A} = S \cos a \sin a.$$

As tests on concrete prisms show that the angle of shear is about 60 degrees, the shearing stress at this angle would be $S \times .5 \times .86 = .43$ S. But as the column is hooped, the horizontal component of this shearing stress will have to be resisted by the hoops; this is therefore the bursting pressure which we will call X and is found to be cos a times the shearing stress, or $X = .5 \times .43\ S = .215\ S$ when $a = 60°$.

In order to derive a simple formula for use in designing hooped columns it is assumed that the column as a whole will sustain a safe load of from 1,000 to 1,400 pounds per square inch, according to the richness of the concrete, and dividing the load to be carried by the safe working stress will give the area of the column within the hooping, sufficient thickness of concrete being allowed over the hooping for fire protection.

Having determined the size of the column, the area of the longitudinal rods near the outside of the column can be obtained by taking two per cent. of the area of the concrete core as the area of these rods.

The area of the hooping metal and spacing can be found as follows: Subtract from the total load on the column the resistance of the outside longitudinal rods figured at the unit stress of 12,000 pounds per square inch; divide this difference by the area of the column core, which will give the unit stress on the concrete; the unit bursting pressure will equal .215 times this stress; assume the spacing of the hoops to be one-seventh or one-eighth the diameter of the columns and multiply one-half the diameter of the column core by the distance on centers of the hoops and by the unit bursting pressure, and divide this product by the safe working stress of the material of the hoops and the quotient will be the area of the hoops. Very frequently more than two per cent. of longitudinal rods will be required, especially for high buildings and where the size of the columns must be kept down to within small dimensions. In these cases, the additional rods may be located near the center of the column and their size be determined by allowing the same working stresses on them as are allowed on other longitudinal rods.

The above rule for designing hooped columns compares very favorably with the results of tests made by M. Considére, and it has been used in designing a six-story building.

National Association of Cement Users.

PHILADELPHIA, PA.

STANDARD BUILDING REGULATIONS FOR THE USE OF REINFORCED CONCRETE.

Adopted February, 1910.

I. General.

1. The term "Reinforced Concrete" shall be understood to mean an approved concrete which has been reinforced by metal in some form so as to develop the compressive strength of the concrete. **Definition of Reinforced Concrete.**

2. Reinforced concrete may be used for all classes of buildings if the design is in accordance with good engineering practice and stresses are figured as indicated in these regulations. **Class of Buildings.**

3. There shall be no limit upon the height of buildings of reinforced concrete except as limited by the requirements in these regulations. **Height of Buildings.**

4. Before permission is granted by the Building Department to erect any reinforced concrete building, complete plans, accompanied by specifications, signed by the engineer and architect, must be filed with the Building Department and remain on file for public inspection until the building is completed. **Plans.**

5. The Building Department shall have access to the computations, which shall give the loads assumed separately, such as dead and live loads, wind and impact, if any, and the resulting stresses.

6. The specifications shall state the qualities of the materials to be used for making the concrete, and the proportions in which they are to be mixed. **Specifications.**

7. Upon the completion of the building the engineer and architect shall issue, under the approval of the Building Department, signed certificates, to be posted on each floor of the building, stating the safe carrying capacity per square foot.

Records. 8. There shall be kept an exact record of the progess of each operation where the same can be inspected by the Building Department. These records shall show the date of placing of all the concrete and date of removal of the forms, and must be turned over to the Building Department when the building is completed.

Walls. 9. Where reinforced concrete is used for walls, the thickness may be two-thirds of that required for brick or stone walls. Curtain walls shall not be less than four (4) inches thick.

10. Concrete walls must be reinforced in both directions. The maximum spacing of reinforcing bars shall be 18 inches between centers, reinforcement in both faces of the wall being considered. Total reinforcement shall not be less than one-fourth (¼) of one per cent.

Tile and Joist Construction. 11. Wherever floor constructions are built with a combination of tile or other fillers between joists, the following rules regarding the dimensions and methods of calculations of construction shall be observed.

(*a*) Ratio of minimum depth to clear span of joist shall not be greater than one to eighteen.

(*b*) Wherever a portion of the slab above the tile joist shall be considered as acting as a Tee-beam section, the slab portion must be cast monolithic with the joist and must have a minimum thickness of at least 2 ins. on all spans. Otherwise, all regulations applying to Tee beams shall apply to tile and joist construction.

(*c*) Where the joists are figured as rectangular beams, in accordance with the standard regulations for this type of beams, the slab shall be considered as independent of the structural part of the building.

(*d*) Wherever porous tiles, or other materials which by their nature will absorb water from the concrete, are used between the joists, care must be taken to thoroughly saturate the tiles, or other materials, with water immediately before the concrete is placed.

(*e*) Reinforcement for slabs over joist construction below 30-in. centers need not be closer than 24 ins. in each direction.

II. MATERIALS.

a. CEMENT.

12. Only Portland cement shall be used in reinforced concrete structures. Portland cement shall meet the requirements of the Standard Specifications for Cement of the American Society for Testing Materials. (See Standard No. 1 of the National Association of Cement Users.) **Cement.**

13. Tests of cement used in building operations shall be made from time to time under the supervision of the Building Department in accordance with the preceding specifications. No brand of cement which has not met these requirements shall be used.

b. AGGREGATES.

14. Extreme care shall be exercised in selecting the aggregate for mortar and concrete, and careful tests must be made, where any doubt exists, of the materials for the purpose of determining their qualities and the grading necessary to secure maximum density or a minimum percentage of voids. **Aggregates.**

15. *Fine aggregates* shall consist of sand, crushed stone or gravel screenings, passing when dry a screen having one-quarter inch diameter holes, and not more than six per cent. passing a sieve having 100 meshes per lineal inch. It shall be of clean, silicious material free from vegetable loam or other deleterious matter.

16. Mortars composed of one part Portland cement and three parts fine aggregate by weight when made into briquettes should show a tensile strength of at least 70 per cent. of the strength of 1 : 3 mortar of the same consistency made with the same cement and standard Ottawa sand.

17. *Coarse aggregate* shall consist of inert material, such as crushed stone, or gravel, which is retained on a screen having one-quarter inch diameter holes, the particles shall be clean, hard,

durable and free from all deleterious material. The maximum size of the coarse aggregate shall be such that it will not separate from the mortar in laying and will not prevent the concrete fully surrounding the reinforcement or filling all parts of the forms.

18. The maximum size for reinforced concrete shall be such that all the aggregate shall pass a one and one-quarter inch diameter ring.

Cinder Concrete. 19. *Cinder* concrete shall not be used for reinforced concrete structures; it may be used for fireproofing. Where cinders are used as the coarse aggregate they shall be composed of hard, clean, vitreous clinker, free from sulphides, unburned coal or ashes.

c. REINFORCEMENT.

Reinforcement. 20. Medium steel for reinforcement of concrete shall be made from new billets and shall conform to the requirements of the specifications for structural steel adopted by the American Railway Engineering and Maintenance of Way Association.

The Building Department shall at its option in lieu of this grade of steel accept medium steel meeting the requirements of the manufacturers' standard specifications, provided the Building Department shall be furnished with the results of two tests made originally by the manufacturer. Tests being taken from each melt, one for bending and one for tension, and provided further that the contractor furnishing such steel shall furnish such additional bars of all sizes for thoroughly testing by the Building Department.

21. *High Elastic Limit Steel.* Where steel is required having an elastic limit between 50,000 and 65,000 lbs. per sq. in., it shall (1) have an elongation in per cent. in eight (8) inches of $\frac{1,000,000}{\text{ultimate strength}}$ and (2) be capable of bending cold 180 degrees around four (4) diameters without fracture.

III. DETAILS OF CONSTRUCTION.

a. MIXING.

Mixing. 22. *General.* The ingredients of concrete shall be thoroughly mixed to the desired consistency, and the mixing shall continue

until the cement is uniformly distributed and the mass is uniform in color and homogeneous.

23. Methods of measurement of the proportions of the various ingredients, including the water, shall be used, which will secure separate uniform measurements at all times. **Measuring Proportions.**

24. *Machine Mixing.* When the conditions will permit, a machine mixer of a type which insures the proper mixing of the materials throughout the mass shall be used.

25. *Hand Mixing.* When it is necessary to mix by hand, the mixing shall be on a water-tight platform, and especial precautions must be taken to turn the materials until they are homogeneous in appearance and color.

26. *Consistency.* The materials must be mixed wet enough to produce a concrete of such a consistency as will flow into the forms and about the metal reinforcement, and which, on the other hand, can be conveyed from the mixer to the forms without separation of the coarse aggregate from the mortar.

27. *Retempering* mortar or concrete, *i. e.*, remixing with water after it has partially set, shall not be permitted.

b. PLACING OF CONCRETE.

28. *General.* Concrete shall be placed in the work immediately after mixing and deposited and rammed or agitated by suitable tools in such a manner as to produce thoroughly compact concrete of maximum density. No concrete should be placed until the reinforcement has been placed and firmly secured by wiring or other methods to prevent displacement. **Placing of Concrete.**

29. The faces of concrete exposed to premature drying shall be kept damp for a period of at least seven days.

30. Before placing the concrete care shall be taken to see that the forms are substantial and thoroughly wetted and the space to be occupied by the concrete free from débris. When the placing of the concrete is suspended, all necessary grooves for joining future work shall be made before the concrete has had time to set.

31. When work is resumed, concrete previously placed shall be roughened, thoroughly cleansed of foreign material and

laitance, drenched and slushed with a mortar consisting of one part Portland cement and not more than two parts fine aggregate.

32. *Placing in Water.* Concrete should not be placed in water, unless unavoidable. Where concrete must be placed under water, unusual care must be taken to prevent the cement from being floated away.

33. *Freezing Weather.* Concrete shall not be mixed or deposited at a freezing temperature unless special precautions are taken to avoid the use of materials containing frost or covered with ice crystals, and to provide means to prevent the concrete from freezing after being placed in position and until it has thoroughly hardened.

c. PLACING OF REINFORCEMENT.

Placing of Reinforcement.

34. The reinforcement shall be accurately located in the forms and secured against displacement.

d. JOINTS.

Joints.

35. *Reinforcement.* Wherever it is necessary to splice reinforcement by means of lapping, the length of the lap shall be determined upon the basis of the safe bond stress and the stress in the bar at the point of splice; or a connection shall be made between the bars of sufficient strength to carry the stress. Splices at the point of maximum stress must be avoided.

36. In columns large bars (bars with area equal to one and one-fourth inches diameter round or larger) shall be properly butted and spliced. Smaller bars may be lapped as indicated in paragraph 35.

37. *Concrete.* Reinforced concrete work shall be stopped at such points that the joints will have the least possible effect on the strength of the structure. Footings shall be cast to their full depth at one operation.

(*a*) *Columns.* Work in columns shall be stopped at the underside of the lowest projections at the head of the columns.

(*b*) *Beams and Girders.* Construction joints in beams and girders shall be vertical and within the middle third of the span. Any concrete which may run past the bulkheads must be cleaned

up before the concreting of the next section is started. Where brackets are used, the bracket shall be considered as a part of the beam or girder.

(*c*) *Slabs.* Construction joints in slabs shall be near the center of the span. No joint will be allowed between slab and beam or girder.

e. REMOVAL OF FORMS.

38. Under no consideration shall forms be removed until the concrete has hardened sufficiently to permit their removal with safety. **Removal of Forms.**

39. *Floor Slabs and Beams.* Forms shall not be removed from floor slabs in less than seven days. Sides of beams may be removed at the same time as the floor slabs provided original supports under beams and girders are left in place.

40. *Columns.* Where original supports remain under beams and girders coming to the columns, the forms shall not be removed from the columns in less than four days.

41. *Beam and Girder Supports.* The original supports for all beams and girders must remain in place at least ten days, but all beams and girders having more than thirty feet span from center to center of support shall be considered as special cases and shall be subject to inspection of the Building Department before removal of supports. The length of time before the removal of forms shall be increased in all cases and additional time for each and every day that the thermometer registers anytime during the day or night below 35 degrees Fahrenheit. **Removal of Supports from Beams and Girders.**

IV. DESIGN.

a. GENERAL ASSUMPTIONS.

42. *Internal Stresses.* As a basis for calculations for the strength of reinforced concrete construction, the following assumptions shall be made:

(*a*) A plane section before bending remains plane after bending.

(*b*) The modulus of elasticity of concrete in compression within the usual limits of working stresses is constant.

(*c*) In calculating the moment of resistance of beams the tensile stresses in the concrete shall be neglected.

(*d*) Perfect adhesion is assumed between concrete and reinforcement. Under compressive stresses the two materials are therefore stressed in proportion to their moduli of elasticity and their distance from the neutral axis.

(*e*) The ratio of the modulus of elasticity of steel to the modulus of elasticity of concrete shall be assumed to be 15.

(*f*) No allowance shall be made for tension in concrete.

(*g*) Initial stress in the reinforcement due to contraction or expansion in the concrete may be neglected.

(*h*) In columns the ratio of least diameter to height shall be taken as one-fifteenth. Greater ratios shall be deduced by satisfactory column formulæ.

43. *Length of Beams and Slabs.* The span length for beams and slabs shall be taken as the distance from center to center of supports, but shall not be taken to exceed the clear span plus the depth of beam or slab. Brackets shall not be considered as reducing the clear span.

44. *Length of columns* shall be taken as the maximum unsupported length.

45. Where *slabs and beams* are figured as simple beams the length shall be considered as the clear distance betweeen supports excluding brackets.

b. LOADS.

Loads. 46. The *dead load* shall include the weight of the structure and all fixed loads and forces.

47. The weight of the reinforced concrete shall be taken as 150 pounds per cubic foot.

48. The *live load* shall include all loads and forces which are variable.

The minimum live load for floors and roofs shall be as generally provided by building codes.

49. *Roof and Floor Loads.* The roof shall be figured to carry 30 pounds live load per square foot unless otherwise noted.

50. A reduction of live load coming to the column supporting the floor below the roof of 5 per cent. to be allowed and a

further reduction of 5 per cent. of the live load of each story below until the total reduction shall amount to 50 per cent. of the live load of any floor, after which all loads shall be figured net to the foundations. These reductions shall not appply to storage warehouses.

51. *Reduction of Loads.* No reduction of loads shall be allowed for figuring floor slabs.

52. No reduction of loads shall be allowed for figuring beams.

53. A reduction of 15 per cent. live load may be allowed in figuring the girders, except in buildings used for storage purposes.

54. In assuming the load coming to the columns all beams and girders shall be considered as carrying a net load consisting of 100 per cent. each of live and dead load, subject to the above reductions.

c. BENDING MOMENTS.

55. *Slabs.* The bending moment of slabs uniformly loaded and supported at two sides only shall be taken as $\frac{1}{8}$ wl^2, where w = unit load and l = span. **Bending Moments.**

56. *Continuous Slabs.* For interior slabs overhanging two or more supports the bending moment shall be taken as $1/12\ wl^2$. The reinforcement at the top of the slab over supports must equal that used at the center.

57. *Slabs Reinforced in Both Directions.* Slabs that are reinforced in both directions and supported on four sides and fully reinforced over the supports (the reinforcement passing into the adjoining slabs) may be figured on the basis of bending moments equivalent to $\frac{wl^2}{F}$ for load in each direction. When span under consideration is not continuous, F = 8; when continuous over one support, F = 10; when continuous over both supports, F = 12. The distribution of the loads to be determined by the formula:

$$r = \frac{L^4}{L^4 + b^4}$$

in which r equals proportion of load carried by the transverse reinforcement, L equals length of span, and b equals breadth of slab.

58. The slab area may be reduced by one-half, as above figured, when the reinforcement is parallel to and not farther from the supports than one-quarter of the shortest side.

The reinforcement spanning the shortest direction shall be below the reinforcement spanning the longer direction, and shall not be further apart than 2½ times the thickness of the floor including the finish.

Simple Beams.

59. *Simple Beams.* The bending moment of beams supported at the ends only shall be figured as of simple beams.

Partially Restrained Beams.

60. *Partially Restrained Beams.* Beams supported at one end and continuous at the other to be figured partially restrained with a bending moment of eight-tenths (0.8) that of a simple beam.

When the overall vertical distance of the tension members is greater than one-sixth of the total depth of the beam the stresses in each member shall be computed in proportion to the distance from the neutral axis.

61. Beams supporting rectangular slabs reinforced in both directions shall be assumed to take the following load: The beams on which the shortest sides of the slab rest shall take the load of that portion of the slab formed by the isoceles triangle having this side as its base and half this side as its height. The load from the remaining portion of the slab shall go to the beams on which the long side of the slab rests.

Continuous Beams.

62. *Continuous Beams.* When beams or girders are continuous over two or more supports, the interior beams may be considered as partially restrained, and the bending moments at the center and support figured as two-thirds (2/3) that of a simple beam, unless the concrete at the bottom of the beam at the support shall by this consideration receive excess compression.

Tee Beams.

63. *Tee Beams.* In beam and slab construction, an effective metallic bond shall be provided at the junction of the beam and slab. When the principal slab reinforcement is parallel to the girder, transverse reinforcement shall be used extending over the girder and well into the slab.

64. Where adequate bond between slab and web of beam is provided, the slab may be considered as an integral part of the beam, but its effective width shall not exceed one-sixth of the span

length of the beam on either side of the beam, nor be greater than six times the thickness of the slab on either side of the beam. Measurements from the edge of the web.

65. In the design of Tee beams acting as continuous beams, due consideration should be given to the compressive stresses at the support at the bottom of the beam.

d. WORKING STRESSES.

66. Concrete composed of materials meeting the requirements **Concrete.** of these regulations, mixed in proportion of one part of cement and six parts of aggregate (fine and coarse), shall develop a compressive strength of 2,000 pounds per square inch in 28 days when tested as 8-in. diameter cylinders 16 ins. long under laboratory conditions of manufacture and storage, using the same consistency as is used in the field. When the proportion of cement is increased, using the best quality of aggregates, an increase may be made in all working stresses proportional to the increase in compressive strength at 28 days, as determined by actual tests, but this increase shall not exceed 25 per cent. On this basis the following working stresses shall be allowed in construction:

67. *Bearing* compression, 650 pounds per square inch.

68. *Compression* in extreme fiber, 650 pounds per square inch. With increase of 15 per cent. near supports in continuous beams.

69. *Axial compression* in columns *without hoops,* 450 pounds per square inch and 6,750 pounds per square inch on vertical reinforcement.

70. *Axial compression* in columns with 1 *per cent. of hooping,* 540 pounds per square inch, and 6,750 pounds per square inch of vertical reinforcement.

71. *Axial compression* in columns with 1 per cent. hooping and 1 to 4 per cent. of vertical reinforcement, 650 pounds per square inch on the concrete and 9,750 on the vertical reinforcement.

Where it becomes necessary or desirable to use vertical reinforcement of size equal to or larger than a section 1¼-in. round bar, the ends of all longitudinal reinforcing members must be fin-

ished to a plain bearing surface and provision shall be made for properly holding reinforcing members in line, and while the concrete is being deposited.

The bars in the base of such columns shall bear on a plate or casting, or shall be enlarged so as to reduce the bearing stress at the bottom to the stress given in paragraph 67. In lieu of plate the enlargement for bearing the stress may be distributed to the footing by means of dowels with planed upper ends, length of the dowels being sufficient to distribute the stress by means of the bond of the dowel.

In the footing the concrete bond stress to be as given in paragraph 74. The footings supporting columns where hooping and vertical reinforcement is used shall be enlarged to at least six inches on each side of the column, measurements being taken from the center of the hooping.

Bars composing longitudinal reinforcement shall be straight and shall have sufficient lateral support to be securely held in place until the concrete is set.

The clear spacing of bands or hoops shall not be greater than one-fourth the diameter of the enclosed column. Adequate means must be provided to hold bands or hoops in place so as to form a column, the core of which shall be straight and well centered.

Bending stresses due to eccentric loads must be provided for by increasing the section until the maximum stress does not exceed the values above specified.

72. *Compression* on columns reinforced with *structural steel units* which thoroughly encase the concrete core, 540 pounds per square inch on the concrete and 8,100 pounds per square inch on the structural steel.

73. *Web Stresses.* In calculating web reinforcement the concrete shall be considered to carry 40 pounds per square inch, the remainder to be provided for by means of reinforcement in tension.

Members of web reinforcement shall be embedded in the compression portion of the beam so that adequate bond strength is provided to fully develop the assumed strength of all shear reinforcement. They shall not be spaced to exceed three-fourths (¾) of the depth of the beam in that portion where the shear-

ing stresses exceed the allowable shearing value of the concrete. Web reinforcement, unless rigidly attached, shall be placed at right angles to the axis of the beam and looped around the extreme tension member.

74. *Bond* between plain bars and concrete, 80 pounds per square inch of surface of bar; where adequate mechanical bond is provided the stress shall not exceed 150 pounds per square inch of surface of bar.

75. The *ratio of modulus of elasticity* of concrete to steel shall be considered as one to fifteen. **Ratio of Moduli of Elasticity.**

76. The allowable *tensile stress* in reinforcement to be 16,000 pounds per square inch for medium steel and 20,000 pounds per square inch for high elastic limit steel with adequate mechanical bond. **Reinforcement.**

77. The *compressive stress* in the steel reinforcement to be fifteen times the allowed compression in concrete in which the steel is embedded.

e. FIREPROOFING.

78. The main reinforcement in columns shall be protected by a minimum of two inches of concrete, reinforcement in girders and beams by one and one-half inches and floor slabs by one inch. **Fireproofing.**

REPORT OF COMMITTEE

ON

BUILDING LAWS AND INSURANCE.

Part II. Insurance.

The Committee on Insurance has continued work along the lines set forth in the preliminary report of last year, and believes that the collation of data on insurance of the various types and classes of buildings of concrete construction would be of most value. The Association has now on file a list of about 1,000 concrete buildings, and has written the owners requesting information, as per the Insurance Information Blank shown in Fig. 1. Replies have been received covering about 300 buildings, of which 255 contain complete information. This represents quite an increase over the number of replies received last year.

It will be noticed that there are no rates of insurance given for cement hollow block buildings. The members of this Association who are interested in the matter of rates for cement hollow block buildings have been repeatedly requested during the year and also at the annual convention to send in the names of the owners of such buildings in their territory and the failure of the Committee to secure rates is due to the failure of these members to respond to the Committee's request.

The Committee would again make an appeal for information as to the name and address of the owners of cement hollow block buildings in order that they may secure rates for this class of buildings.

BUILDINGS AND CONTENTS CARRYING NO INSURANCE.

Special attention is called to the fact that the information the Committee has collated shows that 26.6 per cent. of the buildings covered by replies are not insured by the owners, the type

NATIONAL ASSOCIATION OF CEMENT USERS
HARRISON BUILDING, PHILADELPHIA, PA.

BLANK No. ....
RECEIVED ....
CLASS ....
TERRITORY ....
RATE B. .... C. ....
RISK ....

INSURANCE INFORMATION BLANK

1. Name of Building ....
2. Location. State .... City .... Street .... No. ....
3. Owner. Name .... Address ....
4. Architect. Name .... Address ....
5. Builder. Name .... Address ....
6. Business carried on in Building ....
7. Character of Contents ....
8. Description of Building:
   - *a. Type of Construction.* 1. Reinforced Concrete throughout.
     2. " " columns, beams and floors with brick or stone walls.
     3. Concrete Blocks or concrete bricks.
   - *b. Dimensions.* 1. Number of stories above sidewalk ....
     2. Total height in feet above sidewalk ....
     3. Width in feet ....
     4. Depth in feet ....
9. Fire Protection:
   - *a. Fire Service.* 1. Have you City fire service? .... High pressure Water plugs? ....
     2. Is it paid or volunteer fire service? ....
     3. Have you No fire service? ....
   - *b. Character of surroundings of building.* 1. North side ....
     2. South side ....
     3. East side ....
     4. West side ....
   - *c. Protection of Exterior Openings.* 1. Are the openings protected with metal frames and wire glass? ....
     2. " " " " " tin covered or metal shutters? ....
     3. Is building provided with outside sprinklers? ....
   - *d. Interior fire apparatus.* 1. Is building provided with a sprinkler system? ....
     2. " " " " fire pumps? ....
     3. " " " " tanks or reservoirs? ....
     4. " " " " standpipe with hose connections? ....
     5. Have you a watchman? .... Night? .... Day? ....
   - *e. Are stairways and elevators protected and similar openings enclosed?* ....
10. Insurance. *a.* Rate on building .... Per cent. of cost covered ....
    b. Rate on contents .... Per cent. of cost covered ....
    c. Is insurance carried in a stock or mutual company? ....
    d. Do you carry your own insurance? ....
11. Have you had a fire in any part of building? Please make remarks on reverse side of this sheet.
12. Blank filled out by .... Date ....

FIG. I.—COPY OF INSURANCE INFORMATION BLANK.

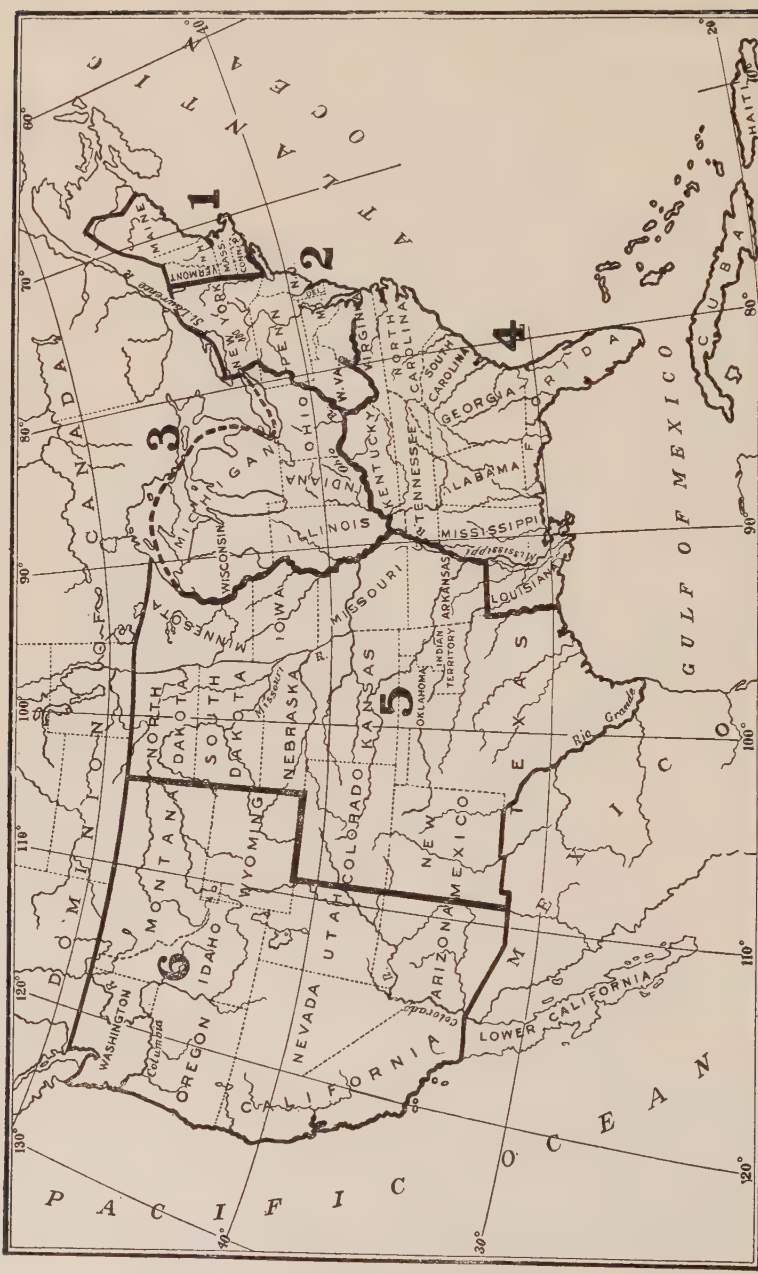

FIG. 2.—MAP SHOWING INSURANCE DISTRICTS.

of construction being in each case considered sufficiently fireproof as to render insurance unnecessary. Some owners even do not consider it necessary to insure the contents of their buildings, because either, the contents are not likely to be destroyed by fire, or the fire could be confined to one room, or in some cases, because the insurance companies specify prohibitive rates due to the inflammable character of the contents. The Committee has been advised by several owners that they have had a fire in one room of their building and that the same was confined to that room. The owners claim that the loss sustained in such cases would be a great deal less than the premiums required to carry insurance.

A few of the typical remarks made by owners of buildings carrying no insurance, might be of interest:

"We think so highly of reinforced concrete construction that we do not carry any insurance on our plant nor contents."

"We consider the cement building absolutely fireproof, and therefore carry no insurance."

"We are not afraid of fire either within or without. Rates will have to be low to induce us to carry insurance."

"None (no insurance) at present and consider it unnecessary with such construction."

"No insurance" (three buildings).

"Do not carry any insurance."

"Our building does not contain a stick of wood, and is so absolutely fireproof that the Directors considered it useless to carry insurance, notwithstanding the fact that the —— companies give us a rate of 7½ cents."

"No insurance. Feel safe as it stands."

EXPLANATION OF TABLES.

Classification. The Committee has classified the buildings upon which reports have been received, indicating for each class the general use of the buildings. It must always be borne in mind, however, from an insurance point of view, that for an exact rate each case should be considered separately and judged on its own peculiar conditions.

Where information is desired by the members of this Association as to the rate of insurance on special buildings, an aver-

age rate will be gladly furnished upon application. It will not be possible, however, to give the rate on any one particular building inasmuch as the information obtained from the owners is confidential.

Districts. In each class the rates have been distributed in six districts according to the location of the buildings. The territory covered by each district is shown on the map, Fig. 2.

Column B. This column in each district covers the rate on the building only.

Column C. This column in each district covers the rate on the contents only of each building.

Summary for all Districts. This column covers a summary of the various rates, averages, etc., for each classification.

Minimum Rate. This covers the minimum rate on buildings only for each district and each class, not considering buildings carrying no insurance.

Maximum Rate. This covers the maximum rate on buildings only for each district and each class.

Average Rate A. This represents the average of all rates reported, exclusive of buildings carrying no insurance.

Average Rate B. The Committee considers that all rates of insurance on buildings above .50 per cent., or 50 cents per $100 insurance, are abnormally high. It has been considered valuable, therefore, to give an average rate excluding all such high rates. The average rate B represents the average of all rates of .50 per cent. or less. Under each class are given, in so far as the Committee has been able to determine, the conditions which might explain the reasons for the high rates.

Number of Risks Rated. This gives the total number of buildings carrying insurance as covered by the table for each district or class.

Number of Risks not Insured. This gives the total number of buildings in each district or class, reported to the Committee as not being covered by insurance.

Total Number of Risks Reported. This gives the total number of buildings in each district or class covered by the table including buildings not insured.

TABLE I.—LIGHT MANUFACTURING BUILDINGS.

	1		2		3		4		5		6		Summary for all Districts.
	B	C	B	C	B	C	B	C	B	C	B	C	Buildings only.
	.20		.10	.15	.04	.07	.15	.15	.133	.40	.35	.60	
	.20	.20	.122	.214	.06	.06	.20	.30	.15		1.77	1.18	
	.50	.50	.13	.17	.075	.075	.50	.75	.40	1.10			
	1.50	2.00	.15	.15	.13				.54	1.07			
			.15	.15	.15	.15			.70	.40			
			.15	.15	.15	.15							
			.15	.15	.16	.25							
			.15	.15	.27	.27							
			.18	.72	.30	.60							
			.31	.60	.30	.61							
			.34	.04	.38	.88							
			.34	.47	.412	.412							
			.36	.81	.60	1.24							
			.38	.73	.61	1.24							
			.40	.75	.75	1.16							
			.43	.71	.90	.90							
			.50	.75	1.20	1.48							
			.88										
			.88	1.25									
			1.—	1.—									
			3.—	3.75									
Minimum rate	.20		.10		.04		.15		.133		.35		.04
Maximum rate	1.50		3.—		1.20		.50		.70		1.77		3.—
Average rate, A	.60		.48		.38		.28		.40		1.06		.46
Average rate, B	.30		.26		.20		.28		.23		.35		.24
Number of risks rated	4		21		17		3		5		2		52
Number of risks not insured	—	—	1	1	5	5	—	—	1	1	—	—	7
Total number of risks reported	4		22		22		3		6		2	2	59

TABLE II.—HEAVY MANUFACTURING BUILDINGS.

	1		2		3		4		5		6		Summary for all Districts.
	B	C	B	C	B	C	B	C	B	C	B	C	Buildings only.
	.016		.07	.07	.06		.225	.225	.98	.98	.90		
			.07	.07	.06	.06	1.50	3.—			1.11	1.11	
			.07	.07	.18								
			.07	.07	.18	.18							
			.07	.07	.20	.20							
			.07	.07	.52	.76							
			.15	.15	.60	.60							
			.20	none									
			.22	.22									
			.22	.22									
Minimum rate			.07		.06		.225				.90		.016
Maximum rate			.22		.60		1.50		.98		1.11		1.50
Average rate, A	.016		.12		.26		.86		.98		1.—		.34
Average rate, B	.016		.12		.14		.23		.98		—		.13
Number of risks rated	1		10		.7		2		1		2		23
Number of risks not insured	—	—	14	15	6	6	1	1	—	—	—	—	21
Total number of risks reported	1		24		13		3		1		2		44

TABLE III.—OFFICE BUILDINGS.

	1		2		3		4		5		6		Summary for all Districts.
	B	C	B	C	B	C	B	C	B	C	B	C	Buildings only.
			.09	.20	.15	.60	.40	.70	.25	.64	.34	none	
			.23	.39	.21	none	.60	.75	.40		.50	.75	
			.50		.25				.55		.64	none	
					.30	none					.85	1.20	
					.33	.41					.91		
											.96	1.25	
											.98	.98	
											1.02		
											1.09	1.09	
Minimum rate			.09		.15		.40		.25		.34		.06
Maximum rate			.50		.33		.60		.55		1.09		1.09
Average rate, A			.27		25		.50		.40		.81		.53
Average rate, B			.27		.25		.40		.33		.42		.30
Number of risks rated			3		5		2		3		9		22
Number of risks not insured			2	2	2	4	2	2	2	2	—	2	8
Total number of risks reported			5		7		4		5		9		30

TABLE IV.—RETAIL STORES.

	1		2		3		4		5		6		Summary for all Districts.
	B	C	B	C	B	C	B	C	B	C	B	C	Buildings only.
			.16	.61	.13	.30	.12	.25	.133	.20	.50	.70	
			.27	.64	.15	.15	.25	.40	.18	.42			
					.19	.143	.60	1.02	.90	1.00			
Minimum rate			.16		.13		.12		.133				.12
Maximum rate			.27		.19		.60		.90				.90
Average rate, A			.22		.16		.32		.40		.50		.30
Average rate, B			.22		.16		.19		.16		.50		.21
Number of risks rated			2		3		3		3		1		12
Number of risks not insured			—	—	—	—	—	—	—	—	—	—	—
Total number of risks reported			2		3		3		3		1		12

The buildings have been classified as follows:

TABLE I.—*Light Manufacturing Buildings.*

The buildings covered in this class are used for light manufacturing such as printing, confectionery, clothing, wood and paper boxes, rubber goods, light metal goods, etc.

In determining the average rate B, the following buildings having rates higher than .50 per cent. have been excluded:

District 1. $1.50. Manufacture of rubber substitutes. No fire protection.

District 2. $0.88. Contents inflammable and combustible.

$0.88. Printing and engraving. Metal frames with glass windows; stand pipe and tank. No sprinklers. Old buildings on two sides. This rate seems unreasonably high for the character of the building.

$1.00. Manufacture of oil cloth.

$3.00. Manufacture of mattresses. Wooden buildings on two sides.

District 3. $0.60. Printing daily newspaper. 20 per cent. of cost of building covered.

$0.61. Manufacture of crackers and candy. Metal frames and wire glass windows. No other fire protection.

$0.75. Manufacture of fur coats. No fire protection except hose on each floor.

$0.90. Contents woodwork, boxes, etc. No fire protection in building.

$1.20. Contents groceries, etc. Metal frames and wire glass windows; sprinklers. Frame buildings on two sides. Owner considers rate altogether too high, the Committee concurs in this opinion.

District 5. $0.54. Contents glass, frames, etc. Metal frames and wire glass; standpipe with hose connections.

TABLE V.—WHOLESALE STORES.

	1		2		3		4		5		6		Summary for all Districts.
	B	C	B	C	B	C	B	C	B	C	B	C	Buildings only.
			none .15 .16	.57 .69 .32	.15 .17 .20 .45 .54	.25 .45 .12 .71 1.21	.45		.13 .15 .16 .24 .35	.20 .45 .25 .55 .87	.22 .70	.46	
Minimum rate			.15		.15				.13		.22		.13
Maximum rate			.16		.54				.35		.70		.70
Average rate, A			.16		.30		.45		.21		.46		.28
Average rate, B			.16		.24		.45		.21		.22		.23
Number of risks rated			2		5		1		5		2		15
Number of risks not insured			1	—	1	1	—	—	—	—	—	—	2
Total number of risks reported			3		6		1		5		2		17

TABLE VI.—WAREHOUSES.

	1		2		3		4		5		6		Summary for all Districts.
	B	C	B	C	B	C	B	C	B	C	B	C	
	.12 .13 .20	.35 .25 .40	none .10 .12 .132 .16 .16 .18 .19 .25 .47 .60 .60	.18 .12 .33 .48 .42 .42 1.25 .46 .50 .78 none 1.—	.10 .11 .113 .13 .20 .20 .25 .45 .55 .75 .90 1.75	.35 .11 .46 .13 .50 .50 .80 .78 .55 .90 1.75	.15 .30 .35 .35 .54 .75 .85	.15 .50 .50 .60 1.07 1.25 .85	.09 .60 .85	.17 1.25 .85	.17 1.07		
Minimum rate	.12		.10		.10		.30		.09		.17		.09
Maximum rate	.20		.60		1.75		.85		.85		1.07		1.75
Average rate, A	.15		.27		.46		.47		.50		.62		.39
Average rate, B	.15		.20		.20		.29		.09		.17		.20
Number of risks rated	3		11		12		7		3		2		38
Number of risks not insured	2	2	3	3	4	4	1	1	1	1	—	—	11
Total number of risks reported	5		14		16		8		4		2		49

$0.70. Manufacture of cotton goods, also storage. Metal frames and wire glass; sprinkler system. Tenements on two sides.

District 6. $1.77. Manufacture of chocolate. 12 per cent. of cost covered. Wooden structure on one side

TABLE II.—*Heavy Manufacturing Buildings.*

The buildings covered under this class are used for the manufacture of machinery, automobiles, cement, carriages, etc.

In determining the average rate B, the following buildings having rates higher than .50 per cent. have been excluded:

District 3. $0.52. Ice factory. Lumber yard on one side. The only explanation for the high rate is the fact that the building is located in a village and the only fire service available is volunteer.

District 4. $1.50. Building used for kiln-drying lumber. Wooden sheds on two sides. Sprinkler system.

District 6. $0.90. Contents machinery, rubber, drugs, and wire. 11 per cent. of cost covered.

$1.11. Blanket rate, covering both building and stock.

TABLE III.—*Office Buildings.*

The buildings in this class are used principally for office purposes, there being in some cases stores in the first floor.

TABLE IV.—*Retail Stores.*

The buildings covered under this class are used for the retail sale of clothing, furniture, hardware and as department stores.

In determining the average rate B, the following buildings having rates higher than .50 per cent. have been excluded:

TABLE VII.—MISCELLANEOUS BUILDINGS.

	Apartments.		Banks.		Club Houses.		Dwellings.		Hospitals.		Hotels.		Libraries.		Stables Garages.	
	B	C	B	C	B	C	B	C	B	C	B	C	B	C	B	C
	.25		.30	.39	.04	.04	.16	none	.088	.64	.15	1.12	.15	.30	.23	none
	.49		.65		.142	.392			.13	.14	.33	.33	.15	.30	.265	.26
					.23	.43			.50	none	.60	1.00	.33	.68	1.18	1.88
					1.10				.60	.60	.76	none			1.92	2 44
											1.25	none				
Minimum rate....	.25		.30		.04		.16		.088		.15		.15		.12	
Maximum rate ...	.49		.65		1.10				.60		1.25		.33		1.92	
Average rate, A ..	.37		.48		.40		.16		.34		.62		.21		.90	
Average rate, B ..	.37		.30		.14		.16		.24		.24		.21		.25	
Number of risks rated..........	2		2		4		1		4		5		3		4	
Number of risks not insured	—	—	1	1	3	3	7	8	1	2	—	2	—	—	6	7
Total number of risks reported ..	2		3		7		8		5		5		3		10	

TABLE VIII.—SUMMARY.

Use of Buildings.	Minimum Rate.	Maximum Rate.	Average Rate, A.	Average Rate, B.	Number of risks rated.	Number of risks not insured.	Total number of risks reported.
Light manufacturing	.04	3.—	.48	.24	52	7	59
Heavy manufacturing	.016	1.50	.34	.13	23	22	45
Office buildings	.06	1.09	.53	.30	22	8	30
Retail stores..................	.12	.90	.30	.21	12	—	12
Wholesale stores	.13	.70	.28	.23	15	2	17
Warehouses	.09	1.75	.39	.20	38	11	49
Apartments	.25	.49	37	.37	2	—	2
Banks	.30	.65	.48	.30	2	1	3
Club houses	.04	1.10	.40	.14	4	3	7
Dwellings	.16	.16	.16	.16	1	7	8
Hospitals	.088	.60	.34	.24	4	1	5
Hotels........................	.15	1.25	.62	.24	5	—	5
Libraries.....................	.15	.33	.21	.21	3	—	3
Stables, garages..............	.12	1.92	.90	.25	4	6	10

Total number of rates reported................................. 187
Total number of risks not insured.................................. 68

Total number of buildings reported......................... 255

Average rate for all classes of buildings, A....................... .416
Average rate for all classes of buildings, B....................... .22

District 4. $0.60. This covers a series of retail stores one of which is a drug store. 75 per cent. of the cost of the building only is insured. Tenanted buildings cost more.

District 5. $0.90. Building contains seeds and flowers, is adjoined by a frame building on one side, and the only fire service is a volunteer department. 25 per cent. of the cost of the building is insured.

TABLE V.—*Wholesale Stores.*

The buildings covered in this class are used by wholesale dealers in drugs, plumbers' supplies, dry goods, paper, confectionery, etc.

In determining the average rate B, the following buildings having rates higher than .50 per cent. have been excluded:

District 3. $0.54. Paper in cases and bundles.

District 6. $0.70. Wholesale men's furnishing store with no fire protection. The building is adjoined on two sides by brick buildings containing wooden floors.

TABLE VI.—*Warehouses.*

The buildings covered under this class are used for the storage of furniture, groceries, liquor, and general merchandise, cold storage, and miscellaneous products.

In determining the average rate B, the following buildings, having rates higher than .50 per cent. have been excluded:

District 2. $0.60. Cattle hides and tallow.

$0.60. Photograph material and general merchandise.

District 3. $0.55. Cold storage house. Warehouses on two sides, railroad tracks one side. Freight depot discharging and receiving freight. The building is surrounded on three sides by brick warehouses and factories.

	\$0.90.	Storage of wood and the use of packing material.
	\$1.75.	Owners claim rate to be exorbitant, and only 25 per cent. of the cost of the building is carried for that reason. The rate for full insurance is \$2.90. The contents of the building are meats, hides, lards, etc., and the owners have constructed another reinforced concrete building upon which they have decided to place no insurance.
District 4.	\$0.54.	Hides, wool and junk.
	\$0.75.	Storage plant with no fire protection of exterior openings and no interior fire apparatus.
	\$0.85.	Storage of street cars.
District 5.	\$0.60.	General storage house with exterior openings and no protection.
	\$0.85.	Building used for the storage of beer. 8 per cent. of the cost of the building is covered, and the same is adjoined by frame buildings on two sides. No private fire protection.
District 6.	\$1.07.	Storage of wood, paper, and use of paints and varnishes.

TABLE VII.—*Miscellaneous Buildings.*

This class covers apartments, banks, club houses, dwellings, hospitals, hotels, libraries, stables, and garages.

In determining the average rate B, the following buildings have been excluded:

Banks.	\$0.65.	No reason apparent for high rate.
Club House.	\$1.10.	Tenanted building, sleeping quarters, etc. Frame building on one side. No private fire protection.
Hospitals.	\$0.60.	No private fire protection.

Hotels.	$0.60.	Adjoins frame building.
	$0.76.	Warehouse on one side.
	$1.25.	Adjoins frame building with no fire wall.
Stables-Garages.	$1.92.	Livery stable.

TABLE VIII.—*Summary.*

This table contains a summary of the rates on all classes of buildings.

Respectfully submitted,

W. H. HAM, *Chairman,*
EDWARD D. BOYER,
JOHN E. CONZELMAN,
H. S. DOYLE,
EMILE G. PERROT.

TOPICAL DISCUSSION ON INSURANCE.

Mr. Lord.

MR. E. A. LORD.—I wish to ask if in towns where the existing building laws prescribe a fire limit and certain other conditions, whether it would be possible to change those building laws in the future so that buildings constructed with partial stucco exteriors would conform to what would be equal to brick veneer. In our town a 4 in. brick veneer is considered sufficient within the fire limits. The question was raised last year whether a building constructed partially of solid reinforced concrete, with an upper story of cement siding on steel lath, would be allowed within the fire limits.

Mr. Ballinger.

MR. WALTER F. BALLINGER.—A concrete building which we had designed and erected a few years ago went through quite a severe fire. There were a number of frame buildings, some having brick walls and wooden floors and roofs, in the immediate vicinity, and some adjoining this concrete building, which were entirely destroyed. The concrete building in question was a three-story structure about 40 by 100 ft. The second and third stories were used for the drying of glue. There were steam coils at one end to warm the air and fans at the other to pull the air through. Racks of wet glue were placed between these in the second and third stories. The first story was open and had no division wall between it and the adjoining frame building. It was used for washing the glue, and was practically an extension of the frame building, so far as occupancy was concerned. The first story, therefore, had a full exposure to the fire.

The upper stories were supposed to be protected by windows of wire glass and metal frames. It so happened that these windows were open at the time the fire occurred, which was in June, after the glue factory had shut down for the summer, because glue cannot be made in hot weather. The racks were very good fuel for the flames, being piled from floor to ceiling and from wall to wall in the third story, but with sufficient air space between to make very good kindling wood, causing a very severe fire. The wire-glass windows were melted and the frames were injured

somewhat, but after being straightened out were used again. I mention this to illustrate the intensity of the fire. There was a ceiling of expanded metal lath and plaster hung from the bottom of the beams in order to avoid air pockets. The ceiling in the third story was entirely destroyed. Outside of the destruction of the ceiling and the wire-glass windows there was no other damage; that is, the concrete structure in the third story suffered no damage. One of the cantilever beams, which project 5 ft. into the next building, taking the place of posts which had supported the floors in the adjacent building, was spalled off on the bottom, in the form of a wedge-shaped piece about 2 ins. thick by the width of the beam and down to a feather edge about 2 ft. long. This, however, had no appreciable effect on the strength of the cantilever beam, it not having been patched and doing its work to-day. **Mr. Ballinger.**

There was a column in the first story, close to an adjacent building, which had one corner split off. One rod, 1½ to 2 ins., from the two faces near the corner of the column, was exposed for a distance of probably 5 ft. The column continued to do its work, but it was thought best to repair it. This was done by running wire spirally around it and enclosing it with a temporary casing of wood, leaving about 2½ ins. from the original column outward. This was filled with concrete and represented the only repair to the concrete structure, costing about $15.00 on the building valued at about $20,000. The ceiling of wire lath and plaster was renewed at a cost of approximately $300.00, and the restoration of the wire-glass windows cost probably $150.00. About $500.00 or $600.00 constituted the entire loss, or rather, the entire cost of repairs in that building, whereas all the surrounding buildings were totally destroyed.

There was no insurance on this particular building, although all the surrounding structures were insured. A few days after the fire the representatives of the insurance companies met to adjust the loss and held a banquet in this concrete building, wherein they discussed the merits and demerits of concrete construction.

I might mention another case. I have forgotten the exact dimensions of the building, but it was approximately 60 ft. square, or larger, having wire-glass windows on all sides and used for making of metal lockers, in which occurred a varnish fire of

Mr. Ballinger. short duration, but severe while it lasted. It cracked nearly all the wire-glass windows and burned out some of the woodwork, but, otherwise, did no appreciable damage, and none to the reinforced concrete.

We once thought that concrete was absolutely fireproof under all conditions, but now regard it as relatively fireproof, having high fire-resistive properties. If the fire is hot enough and keeps up for a long time, it will destroy concrete or any other material. What would be for all practical purposes fireproof for a building of one occupancy would not be fireproof at all for a building of another occupancy. This must be borne in mind in considering fireproofing. For instance, it would be wasting money to make a building as thoroughly fireproof for a schoolhouse as we should make it for a chair factory.

Mr. Chapman. MR. CLOYD M. CHAPMAN.—I would like to ask as to what took place on the second floor in this glue factory.

Mr. Ballinger. MR. BALLINGER.—The wire-glass windows being closed, held the fire.

Mr. Chapman. MR. CHAPMAN.—It is fair to assume, therefore, that if the windows had been closed on the third floor it would have been saved.

Mr. Lloyd. MR. HARRY A. LLOYD.—I would like to ask what proportion of cement was used in the column and beam damaged in this glue-factory fire. It has been stated that rich concrete is more susceptible to fire damage than lean concrete.

Mr. Ballinger. MR. BALLINGER.—My recollection is that we used a $1:2\frac{1}{2}:5$ mixture; we build with richer mixtures now. I do not think the present regulations of the City of Philadelphia, which require a $1:2:4$ mixture, were then in force.

Mr. Perrot. MR. EMILE G. PERROT.—As to whether a rich mixture is less fireproof than a lean mixture, I beg to differ with the statement made, because I do not think it is a fact substantiated by tests. I remember reading that one of the best ways of fireproofing a building is to make the concrete richer; the richer the concrete the more fireproof the building. Professor Ira H. Woolson has made quite a number of tests and our theory is, that the rich mixture is stronger. Naturally it is more fire-resisting, because the cement as a binding agent has more tensile strength and is more fireproof than the stone. That cement mortar is more

Mr. Perrot. fireproof than stone, has been evidenced by the tests made by the government at St. Louis, in which the stone crumbled, whereas concrete did not. A dense mortar, as far as I can recall, is as fireproof as any structural material. I cannot see why a rich mixture is not fireproof.

Mr. Brett. MR. ALLEN BRETT.—There is a theory to the effect, I believe, that as the heat attacks the cement a film forms which protects the rest of the concrete.

Mr. Perrot. MR. PERROT.—I have seen that in fire tests of cement buildings, where the outside became dehydrated and formed a non-conductor, preventing the heat from penetrating further into the concrete. At the same time I have seen edges which have fused on specimens from a fire test. In other words, the silica in the sand seemed to make a very glassy coating. This did not seem to occur all over, but only in spots where the heat was intense.

Speaking of the dehydration of the outside surface, if the same cement or concrete, after passing through a fire, is exposed to the elements or moisture, etc., it will absorb moisture from the air and become hard again. I tried that by taking a specimen from a fire test and leaving it on a window sill in my office for about a year. When I obtained the sample you could just break it, and after a year a hammer was necessary to break it, showing that the water for crystallization had been afterwards absorbed from the atmosphere.

Mr. Ballinger. MR. BALLINGER.—The subjects of the proposed building regulations and of their effect upon insurance seem closely related. I think it would be well for this Association to co-operate with other societies in the formation of regulations to be urged upon the city authorities for adoption. I am inclined to think that our regulations are as practical and safe as any that have been suggested. I would suggest that our Committee endeavor to co-operate with these other committees and urge upon them the adoption of our regulations. Other associations have been attempting to formulate regulations, but have not made any great progress. The difficulty seems to be that they are waiting for something that shall be ideal and receive unanimous approval. I am afraid this will never be attained. You do not get laws passed by Congress and state legislatures unanimously, as a rule; and I think it would be well if we could co-operate and have a

Mr. Ballinger. uniform standard adopted, even though some little changes may have to be made in our standard to conform with the ideas of other people.

Mr. Perrot. MR. PERROT.—I would state that the regulations are based on the report of the Joint Committee, composed of the members of the various engineering societies, principally the American Society of Civil Engineers, the American Railway Engineering and Maintenance of Way Association, and the American Society for Testing Materials, which serves a basis of recommendation to the American Society of Civil Engineers, with the idea in mind of having uniformity, so that when our Association and the American Society adopt regulations there will be some unity of agreement. Of course when it comes to the insurance side of it, I do not think we will ever agree with the insurance companies, because they want about 4 ins. protection on beams. I do not think anybody will construct a concrete building with 3 or 4 ins. protection. I do not think that is a proper thing to ask anybody to do.

I believe the insurance interests are waiting for us to propose something and then will take the matter up to see if they can approve it. The insurance interests will naturally want the best. They feel that if they put out their regulations now, with the high requirements, that the work being done will be crippled. I attended one of their conventions, the National Fire Protection Association, and the feeling I gathered from the convention was that they did not wish to do anything at that time, as there were other committees at work on the practical side, who would come forward with a report and then their Association could act upon the report that had been accepted. I think we should go ahead the way we have done and let them make their criticisms afterwards. Possibly we can come together later, for the purpose of reaching an agreement in the matter.

Experience shows that the mutual companies are very favorable to reinforced concrete as a risk, and I know that if the occupancy is such that it comes under their regulations they will have no hesitancy in insuring the risk.

Mr. Ballinger. MR. BALLINGER.—I know that the mutual insurance companies have insured reinforced concrete buildings in districts which have usually been considered too congested for them to

enter. In one instance that I recall, a building at Fourth and Arch Streets, Philadelphia, which is practically in the congested district, although not in that which the underwriters call the conflagration district. The latter is still more hazardous, and the mutual companies will not insure there no matter how good the risk. The mutual companies, as many of you know, select their risks and will not insure everything that is offered. In this case they took a building because it was of reinforced concrete, in what is called the congested district, which is next to the most hazardous district in Philadelphia. I refer to the Ketterlinus printing house. Mr. Ballinger.

I have known them in other cases to make exceptions, one being an 8 story reinforced concrete building at Thirteenth and Callowhill Streets, Philadelphia, which is in the congested, but outside of the conflagration district.

The favor with which the mutual companies look upon reinforced concrete is pleasing to us, of course. The difference between mutual and stock companies, is that the mutuals only insure preferred risks. They have been accepting buildings of slow burning construction, if properly equipped and sprinkled, and they regard reinforced concrete construction as highly superior to the slow burning wood constructed building. The stock companies, on the other hand, insure anything from a frame shack to the highest type of fireproof building and adjust the rate accordingly. It is probable that they earn on an average just as much on a non-fireproof building by charging a higher rate, as they can on a fireproof building. When making a rate for a fireproof building, they want to be so sure that it is fireproof, so in case of a severe fire of the contents it will not be necessary to pay a very high loss on the building itself. While there have been quite a number of accidental fires and a great many fire tests of concrete structures, the insurance companies do not consider that the modern reinforced concrete building has been subjected to sufficiently severe conflagrations or fires to thoroughly demonstrate that they will resist fires under all circumstances without causing material loss.

Mr. Mensch. MR. L. J. MENSCH.—After examining some of the concrete buildings subjected to the San Francisco fire in 1906, I am of the opinion that a really fireproof building material does not exist.

Mr. Mensch. The fact is, a coat of several inches of concrete is necessary around the reinforcement so as to make a building absolutely proof against fire in a general conflagration of such intensity. In the Telephone building I saw beams 7½ ins. wide which were reduced to about 4 or 5 ins. by the fire. This building was not entirely completed before the fire, and probably there would have been more heat produced if the building had been completed, with wooden floors, etc. In the Monadnock Building, which has beams 7½ ins. wide, the beams, after the fire, could not be used again. Since then it has been my practice not to build a beam less than 9½ ins. wide in any structure which should be really fireproof. It is always a question whether you want an absolutely fireproof building. In buildings used as residences, apartment houses, hotels, or machine shops, you do not need the same degree of fireproofing, as in buildings which contain a great deal of inflammable material. One concrete building in San Francisco, which was in course of construction when subjected to the fire, had probably had one-half of the beams cracked and in a few cases separation of the beams from the slab took place. In most buildings the beams invariably separated from the slabs. This shows that you have to use stirrups and plenty of them in the beams to assure that such a separation does not take place during a fire.

I had to tear down a building in San Francisco which had steel columns, steel girders, and concrete beams and slabs. The beams were about 6 ft. apart, reinforced with flat irons about 4 ins. wide and ½ in. thick and shaped in a catenary line. All of those beams sagged from 6 to 8 ins. in spans of about 15 ft. The slabs proper were in a fair condition and were tested after the fire with 400 lbs. per sq. ft., which load they stood very well. The building was supposed to be figured for 200 lbs. per sq. ft., but on account of the girders the floors could not be used. The girders were the weak portions of the structures in every case. That is why I advise making girders not less than 9½ ins., and in buildings of great importance probably not less than 12 ins. wide, to insure absolute fireproof qualities in an intense fire of long duration. There were plenty of cases where steel beams buckled 6 and 8 ins. where they were fireproofed with tile. The heat was simply enormous.

Mr. Mensch. A concrete building in Baltimore, after the fire of 1904, had the columns badly spalled. They were probably not fit to carry the loads for which they were figured, although the slabs and girders were found in a fair state of preservation. They showed a great many shearing cracks, also a few cases of separation from the slabs.*

Mr. McCullough. MR. ERNEST MCCULLOUGH.—There was a fire in the storeroom of a chemical manufacturing company in Illinois, and I have been trying to get some information from the adjuster of the insurance company who settled the damage claim. It seems that on the lower floors there were stored several thousand pounds of chemicals and highly inflammable material. The fire raged for several hours, and no damage was done on the second floor. The owner tried to collect from the insurance company for damages to the building. On investigation it was decided that if the deflection exceeded the allowable deflection under the test load prescribed by the architect when the building was erected, then the insurance companies would settle and agree that the floor had been damaged. So the floor above was cleared and a similar test load to the previous one was put on and the deflection was not quite double the deflection under the test load at the time the building was accepted. The company settled for the damage to that floor. I do not think the floor was torn out, but it was simply secured by strutting underneath. When I have the full particulars I will communicate with the Association so they can be published. From the amount of deflection the architect permitted for that floor I do not believe the deflection in the floor would have been considered excessive; in other words, that even after the fire, the reinforcement had not passed the elastic limit.

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* There were only one or two strictly reinforced concrete buildings erected in San Francisco at the time of the conflagration of 1906. There were many buildings of steel construction having floors of cinder concrete carried by a steel frame. This concrete was generally of very poor quality and the test is hardly a fair comparison to concrete of the quality now generally used. The type of flat band reinforcement in the form of a catenary curve referred to by Mr. Mensch was of exceedingly bad design, and failure resulted from the expansion of the exposed reinforcement, as was to be expected. When the concrete construction approached first-class quality the behavior was most excellent, and it can be stated that, under the conditions, concrete construction had decidedly the best record of the various types of construction. Further information concerning the behavior of various structures and structural materials in the San Francisco Earthquake and Fire may be obtained from Bulletin 324, U. S. Geological Survey.—ED.

Mr. McCullough. I have been informed that the reinforcement was only uncovered at one or two places, but the best information I obtained was that these places were only about ½ or ¾ in. from the surface, and the heat from the fire and from those chemicals must have been intense. The insurance companies did say that if it had been any other than a reinforced concrete floor, the entire building and all the contents would have been a total loss. This speaks well for a concrete fireproofed building.

While there may not be an absolutely fireproof building, there can be built a structure, in which the loss of the contents of a floor separated from the one on which the fire occurs, will be small. The only loss will be on the structure itself, which is a very important thing to know. I believe that the greatest damage in any fire of that kind, will be to the beams and girders. The separation of the slab from the beam and girder may not be wholly attributable to temperature stresses occurring at the point of juncture, because there are a great many contractors who do not pour the slabs, beams and girders at the same time.

I think it was the practice in San Francisco to pour the beams and girders first, clean off the surface and give them a wash coat. Some times 20-penny nails were set in pretty thickly to tie the slab to the beam. This was a practice ten or fifteen years ago, and I think a great many of the separations were due to this. Sometimes the greatest interval that existed was six or eight hours, although I have known cases where the slabs were poured the following day.

Now where the T beam section is used so greatly, and slabs and beams are poured at one operation, I do not think there is so much danger of separation. At the same time I advise using stirrups or some kind of shear reinforcement against diagonal tension, run well up into the slab.

Regarding the value of reinforcement for tension in the web, experiments show that the shear reinforcement is not called into service until the concrete nearly fails. Hardly more than 5 or 10 per cent. strength is added on account of the shear reinforcement, but it reduces the deflection. A beam thoroughly reinforced in the web shows about $^1/_3$ or $^1/_2$ the deflection as a beam without web reinforcement.

Mr. W. P. Anderson.—I have made tests of the deflection of beams without stirrups but the results do not correspond with what has been stated. The beams were constructed to fail by shear and they were made in T sections. Some of the beams were 2½ ins., and some 3 ins. thick, and ran about 7 ins. below the slab, which was about 2 ft. wide and 3 or 4 ins. thick. The tension rods in the beams were also excessive, so that the beams had to fail by shear. The beams without any reinforcement failed by shear, at about 200 lbs.; when they were reinforced for shear, up to 1,000 lbs., an increase of 500 per cent. I have no doubt they would go higher if we put in more reinforcement. No matter what the reinforcement was, the concrete shearing cracks occurring at the same load. I believe the reinforcement in buildings acts like a truss, and the concrete takes the compression of the truss and shores up the tension members. A beam will certainly carry much higher loads when the bars are bent up at the end and stirrups are used. **Mr. Anderson.**

Mr. Perrot.—It is possible to design a concrete beam to have a failure almost anywhere. I remember seeing an advertisement by a prominent reinforced concrete concern in which they showed the advantage of stirrups. They had finished a test of a full-size floor girder and slabs, two of them, loaded with iron, in which there was a failure by diagonal tension, and stripping of the rods near the supports. An experienced person would say that they had too large tension rods without any stirrups, and consequently failure by shear. A supplementary photograph showed their system, in which the rods broke in the middle. A small percentage of reinforcement was used in the beam and consequently broke the rods in tension. **Mr. Perrot.**

I have conducted tests of balanced beams in which some of them failed in compression and others in tension, they were so nearly balanced. So it is possible to design to suit almost any condition desired.

I think there should be no building erected without stirrups. Not only to make them fireproof, but also because we never know what is going to happen, when rain is going to come, the men going to strike, or any emergency. You must be ready to meet any emergency.

REPORT OF COMMITTEE ON SPECIFICATIONS FOR FIREPROOFING.

By Rudolph P. Miller, Chairman.

The proper amount of fireproofing material required to safely protect the structural members of buildings against the destructive effect of fire is a question on which opinions, for it is at the present time only a matter of opinion, vary according to the viewpoint. In the protection of the lower flanges of the beams in fireproof floor constructions, for instance, the specifications of some architects and building ordinances call for a full two inches of protection, while on the other hand, it has been seriously argued by builders of good repute, that no protection is required for the soffits of the beams, provided the beams are thoroughly encased on the sides with fireproof materials. Between these extremes there are as many opinions as there are advocates for different materials and systems of construction.

The construction of fireproof floors has received considerable attention from investigators. The Bureau of Buildings of New York City has conducted more than 55 tests on full-sized floor constructions, the British Fire Prevention Committee has made fully 20 such tests, the Underwriters' Laboratories in Chicago have also done work along this line, and here and there isolated tests have been made by individuals and corporations. And yet with all these results at hand, no definite conclusions have been drawn or standard specifications formulated which can be said to have received general acceptance.

Curiously enough, the protection of the most important element in the superstructure of a building, the column, has had least attention paid to it. Practically no tests have been made on the fireproofing of columns, and the requirements for the form of protection are almost entirely a matter of opinion.

In view of these conditions, it was felt by the Committee on Specifications for Fireproofing that the first step toward definite conclusions and satisfactory and acceptable standards would be to gather full and reliable information about the materials used

for fireproofing and their effectiveness as shown by prearranged tests or by actual fires. It can readily be seen that this plan involves much labor and will require time, and it is for this reason that the Committee, composed of men whose occupations keep them busily employed, have not been able to submit to you at this time any definite conclusions. The collection of data has been well under way, but is by no means sufficient along any one line to yield results.

The main work of the Committee, for the present at least, will be to study the question of proper protection for the structural elements of buildings, such as beams, girders, columns, lintels, etc., whether the same are of steel, concrete or any other material. The Committee will also gather all information it can bearing on the proper materials and construction of floor arches, partitions, walls, etc., for future study.

The Committee also feels that its work would not be complete, and not even impartial, if it limited its investigations to cement products, and for that reason is desirous of obtaining data on other materials used for protective purposes.

It can be readily seen that acceptable conclusions must of necessity be based on many considerations, among which the following may be mentioned: Should the proper protection be capable of safely resisting only the ordinary conditions of a fire, or should it provide for the extraordinary conditions as well? What may be accepted as the ordinary conditions of a fire, what temperatures and for what length of time? Can fireproofing be properly graded to suit varying degrees of hazard? What effect, if any, does the composition of the materials have on the efficiency of the protection; is, for instance, any one mixture or proportion of concrete superior to another, or is one kind of clay or terra cotta better suited than another? The thickness and method of application of the protective material must, of course, play very important parts in this investigation.

For the purpose of securing all possible information that can throw any light on the behavior of different materials subjected to fire, a schedule of questions has been prepared and is given at the end of this report. This schedule will indicate along what lines the Committee intends to work, and will serve as a

guide to all who can and will assist the Committee. Any information, even if only partially answering the questions will be appreciated. The results of fire tests, as well as the effects of actual fires, are desired. In all cases the trustworthiness of the information should be shown. No fear need be felt of the possibility of duplicating information, as the Committee would rather submit to the trouble of eliminating than risk the loss of valuable facts. Besides, the same phenomena often impress different observers in different ways, and any subject is best considered when all sides have been impartially heard.

It is fully realized that the complete information as outlined in the schedule can probably not be furnished in many cases, but this should not deter any one from giving so much of the information as can be obtained.

SCHEDULE OF INFORMATION DESIRED ON EFFICIENCY OF FIREPROOFING MATERIALS.

1. Date of occurrence.
2. Place of occurrence.
3. Was it a prepared fire test, or an actual fire?

   If a fire test,

   (*a*) Under whose auspices was test made,
   (*b*) Who was in immediate charge of test,
   (*c*) Was a report made and to whom,
   (*d*) If so, how can copy be obtained?

   If an actual fire,

   (*a*) What was the general character of the construction of the building,
   (*b*) Who was the owner and architect of the building,
   (*c*) What particular fireproofing material was subjected to the fire,
   (*d*) How was the building occupied,
   (*e*) If fire was confined to local areas, how was story or room occupied where fire occurred,
   (*f*) Give all other information that may have any bearing on the topic.
4. What was the material of the construction to be protected, whether steel, cast iron, concrete, masonry, etc.?

NOTE.—The information intended to be covered by the schedule is to apply to any type or material of building construction, floor beams or girders, columns, lintels, trusses, mullions, walls, partitions, ceilings, etc.

5. What material constituted the protective covering?
    (*a*) If *terra cotta*, give detailed information
        of nature of protection,
        of dimensions, including thickness of shells and webs,
        of minimum thickness of covering at points of attack by fire.
        of method of holding in position,
        of character of material, whether porous, semi-porous or dense terra cotta,
        of source of material and place of manufacture,
    (*b*) If *concrete* forming a protection to some other material, give full details
        of thickness of concrete at point of attack by fire,
        of materials constituting concrete mixture,
        of proportion of mixture,
        of age of concrete,
        of source of materials used.
    (*c*) If *reinforced concrete*, give detailed information
        of construction subjected to test, including all outside dimensions of parts subjected to fires,
        of exact position of reinforcement, with reference to outside surfaces,
        of size and dimension of reinforcement,
        of character of reinforcement, whether medium or high carbon steel, plain, deformed or twisted bars,
        of materials constituting concrete mixture,
        of proportion of mixture,
        of age of concrete,
        of method of mixing,
        of sources of materials used in mixture.

6. What constituted the fuel and how close was it to the construction under observation?

    State also amount of fuel and what proportion remained after quenching, and its condition.

7. Was fire in confined place or vented to outside or other areas?

8. What was the temperature to which the fireproofing material was subjected, and how was it determined or estimated?

9. Was water applied at any time during fire?

    If so, state as fully as possible time and duration of application, size of nozzle, water pressure, number of streams, whether applied by employees or by public department, and whether water was also applied from other sources, such as sprinklers.

10. Was construction under observation subjected to any load during fire?

    If so, what constituted load and what was weight of same.

11. Describe in detail, and as fully as possible, the effects of the fire and water on the construction under consideration, including to what extent material disintegrated, deflected, etc.

12. Was construction repaired after fire, or possible of repair?

    If repaired, what constituted the repairs, and what was cost of repairs?

13. State where corroborative evidence may be found for information given.

    What, if any, competent witnesses were there, or where can authentic accounts be found.

CONCRETE CONSTRUCTION WITH SEPARATELY MOLDED MEMBERS AND COSTS.

By Charles D. Watson.*

Two years ago the author presented a paper on the subject of factory-made concrete†, in which was predicted that such construction, besides having other important advantages over monolithic field methods, would prove to be more economical for buildings of limited height, and that in combination with a light structural fireproofed steel frame, or what is known as reinforced steel construction, it would prove equally as economical for buildings of considerable height. The editorial comments of the technical press quite generally took exception to this view, and contended that the method of concrete construction was limited to special low types of buildings, and that its economy would have to be demonstrated. The object of this paper is to describe briefly what has been done with this particular method of construction, and as far as possible to give costs. The author hopes to be able to present sufficient data to show at least that his contention as to its economy is being substantiated by actual results.

The principal advantages of the unit system over the monolithic field method, besides the absence of all form of work, are

1. Speed of erection.

2. Reliability and uniformity of strength, especially so when the members are made in a factory where the proportion of the materials can be kept theoretically correct, and where they can be tested before being placed in the work.

3. Economy of concrete and consequent reduction of dead weight made possible by more economical shape of members, and by the fact that larger working factors for strength of concrete in compression can be used on account of the superiority of the material.

4. Facility with which future alteration can be made.

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* Consulting Concrete Engineer, Syracuse, N. Y.

† See *Proceedings*, Vol. IV, p. 97.

About the only advantage the monolithic has over the unit system is its enormous rigidity, and a slight economy of metal required for reinforcement, due to continuous beams. In tall separately molded unit structures rigidity, at least equal to the present frame construction, can be obtained by proper design of the reinforcement of the supporting frame.

The more prominent examples of buildings constructed entirely of unit concrete members are the Textile Machine Works, Reading, Pa., the new building of the Edison Portland Cement Company, New Village, N. J., and the car barns of the Central Pennsylvania Traction Company. In addition to these the author has designed and supervised the erection of several such buildings during the past summer, one of which is particularly interesting as regards comparative cost, since it illustrates the possibility of the system applied to the higher type of buildings, using the reinforced steel design with unit factory-made floor members.

The building of the Textile Machine Works was built by what is known as the Visintini System. It was designed and the erection by day labor supervised by the Concrete Steel Company of New York. The cost of the concrete frame and floors, exclusive of curtain walls and finish was found to be about 80 cts. per sq. ft. of floor area, not including cost of engineering and general expense. While this would not be considered particularly low for concrete construction, the design of the members was such that they were rather expensive to fabricate, in fact 25 per cent. of this cost was for forms, and carpenter work setting them up. For that reason this building does not give a proper comparison of cost of the two methods.

The building of the Edison Portland Cement Company, constructed by the unit system and described by Mr. Mason* at the Buffalo Convention, show an abnormally low price for unit construction. This structure was a single story mill building 144 ft. by 360 ft., with 32-ft. columns, 24-ft. girders and 12-ft. roof slabs, all made in the field. The concrete members were made and erected for $6.60 per cu. yd. On account of special facilities for erection and handling, such as tracks and

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* See *Proceedings*, Vol. IV, p. 48.

locomotive cranes, and owing to the fact that raw materials were especially cheap, *i. e.* cement was taken at $1.00 per bbl., crushed stone 60 cts. per cu. yd., the unit cost per yard for this structure is doubtless less than would ordinarily be so for such work. Even with the proper charges for plant rental and depreciation, the usual cost of materials, and other fixed charges that

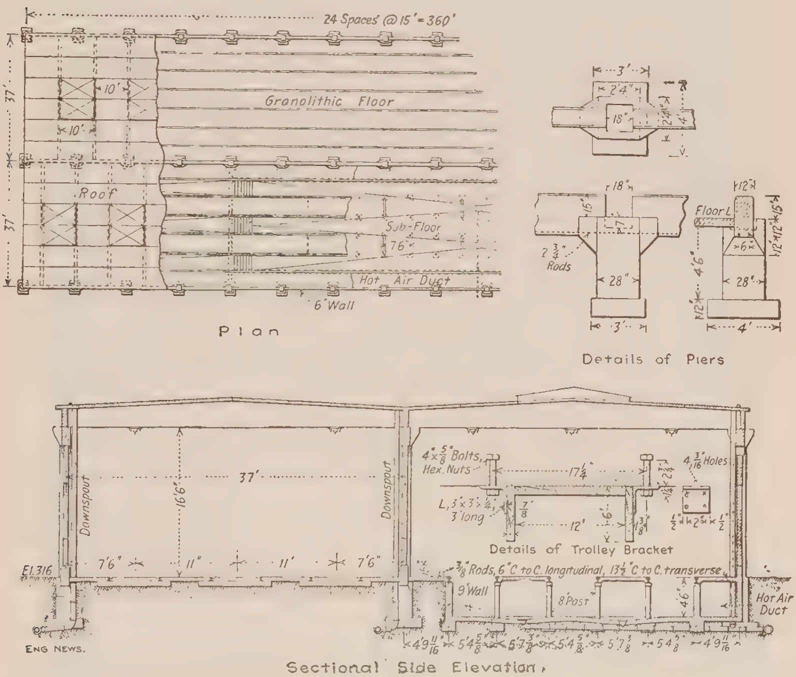


FIG. I.—DESIGN OF CAR BARN, CENTRAL PENNSYLVANIA TRACTION COMPANY, HARRISBURG, PA.

any contractor doing similar work without special facilities would have, it would seem to indicate that $8.00 per cu. yd. for concrete in place would surely have covered the cost under average conditions. Costs of monolithic structures similar to this indicate plainly that the building could not be constructed by the monolithic method for anything like this price.

The car barn of the Central Pennsylvania Traction Company, designed and constructed under the supervision of Mason

FIG. 2.—BAY OF CAR BARN USED FOR CASTING YARD, HARRISBURG, PA.

FIG. 3.—VIEW OF CAR BARN DURING CONSTRUCTION, HARRISBURG, PA.

D. Pratt, City and Constructing Engineer of Harrisburg, Pa., is of exceptional value for the comparison of cost of these two particular types of construction, since four years previous an identical building was constructed by the monolithic system. The following data is supplied by Mr. Pratt.

The building is one story, 75 ft. wide by 360 ft. long divided into two longitudinal bays by a center wall, in which not only the columns and roof are of reinforced concrete, but the walls as well (see Fig.* 1). This building is intended for storage and inspection of electric cars, each bay having three tracks passing entirely through the building. One bay is provided with inspection pits under each track, while the other, which is intended for storage purposes only, has a concrete floor flush with the top of the rails. This latter floor offered a convenient place for a casting yard (Fig. 2), and this fact, together with the large number of duplicate pieces to be made, indicated that there might be some economy in adopting the unit construction. This method was decided on,

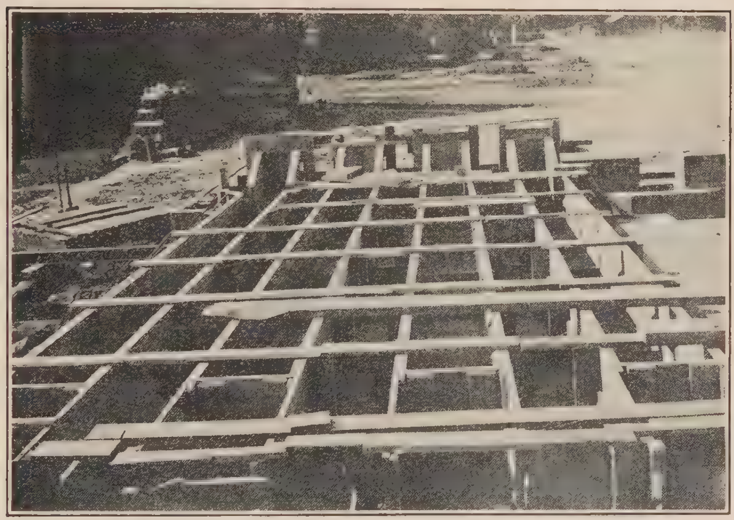


FIG. 4.—FORMS READY FOR CONCRETING, CAR BARN, HARRISBURG, PA.

* Acknowledgment for the cuts used in this paper is made as follows: *Engineering News*, Fig. 1; *Engineering-Contracting*, Figs. 8, 17 and 18.—ED.

and simultaneously with the making of excavations for foundations, the three tracks and the concrete floor were laid in the storage bay and the casting of columns, girders and slabs carried on at the same time with the placing of foundations.

A standard stiff leg derrick with 60 ft. boom was mounted on three trucks each made of two regular street car axles and wheels, the frame of the trucks being 12 x 12 in. timbers. The outer ends of the stiff legs were loaded down with rails and fish plates. A two-drum Lidgerwood hoist mounted on the derrick

TABLE I.—COMPARISON BETWEEN MONOLITHIC (A) AND SEPARATELY MOLDED CONCRETE CAR BARNS (B). (The average values per cubic yard are given, including foundations and superstructure.)

Materials:	A.		B.	
Stone, sand and cement	$3.480		$3.480	
Reinforcement	.915		1.140	
Lumber	1.335		.480	
Paper	......		.040	
Tools, wheelbarrows, etc.	.145		.145	
		$5.875		$5.285
Labor:				
Carpenters	$3.250		$0.965	
Bending and placing reinforcement	.095		.230	
Concreting	2.210		1.685	
Erection	......		1.080	
		5.555		3.960
Total cost per cu. yd.		$11.430		$9.245
		9.245		
Difference in favor of B		$2.185		

platform was equipped with street car motor and controller, and operated with current taken from nearby trolley wire. This derrick traveled on two of the tracks of the inspection bay. It will thus be seen that the various members of the building could be lifted directly from the casting bed to their proper position in the building at one operation (Fig. 3). Some little maneuvering was required in arranging the casting yard not only on account of the limited space but in order to have the proper number of columns beams and slabs in a convenient position for erection.

The forms (Fig. 4) required were of course of the simplest nature, the columns and girders being nested by making the first lot the alternate pieces in the nest at a proper distance apart so that they made the forms for the intermediate piece. The columns on account of having brackets at the upper end were offset longitudinally so that the base of one column cleared the brackets on the upper end of the adjacent columns. The columns and wall slabs were made with tongues and grooves so as to assist in holding them in position during erection. The

FIG. 5.—UNIT CONCRETE FRAME BUILDING IN COURSE OF CONSTRUCTION.

roof beams were arranged to be spaced 10 ft. centers and the roof slabs were thus 10 ft. long and 7 ft. wide. All slabs were cast in piles with ends slightly offset to facilitate picking up. Forty-pound waxed Manila paper was used for separating the pieces and was very satisfactory. This paper was easily removed after the erection was completed by squirting water from an ordinary garden hose.

The total number of separate pieces required for this construction was 1,500 and these were erected with a loss by breakage of only three small pieces in thirty-three working days and by

a gang which had never handled this class of work previously.

That there was a saving in this method of construction over the usual monolithic construction is demonstrated by the costs given in Table I for this building and for an identical building constructed in the usual way four years previously. The rates for labor were practically the same in each case, and for the

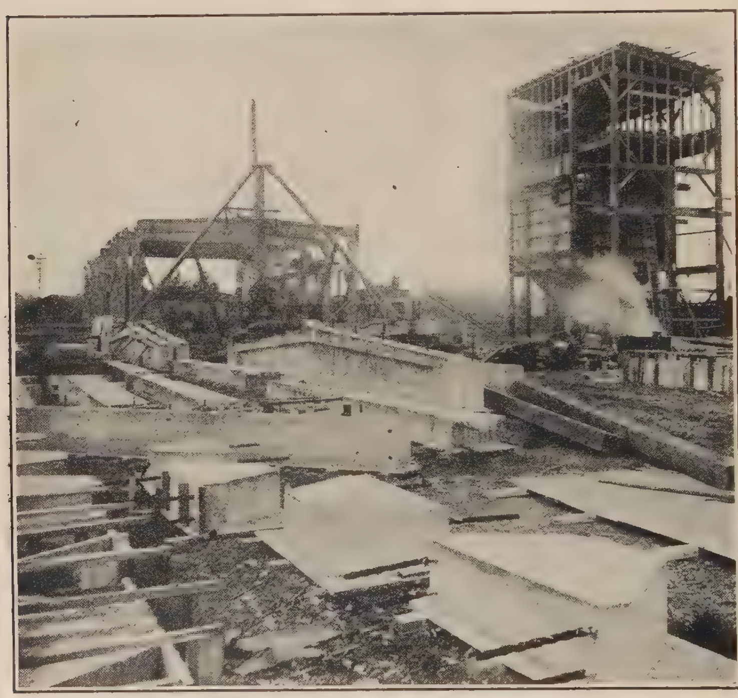


FIG. 7.—CASTING YARD FOR UNIT FRAME MEMBERS.

sake of comparison the cost of the concrete aggregate is made the same in each case.

Unit construction naturally requires the use of more concrete and more reinforcement than mass construction. The figures in this case show a saving per yard of concrete in place of possibly 20 per cent. Taking into account the extra concrete required in the unit construction the net saving was approximately 15 per cent.

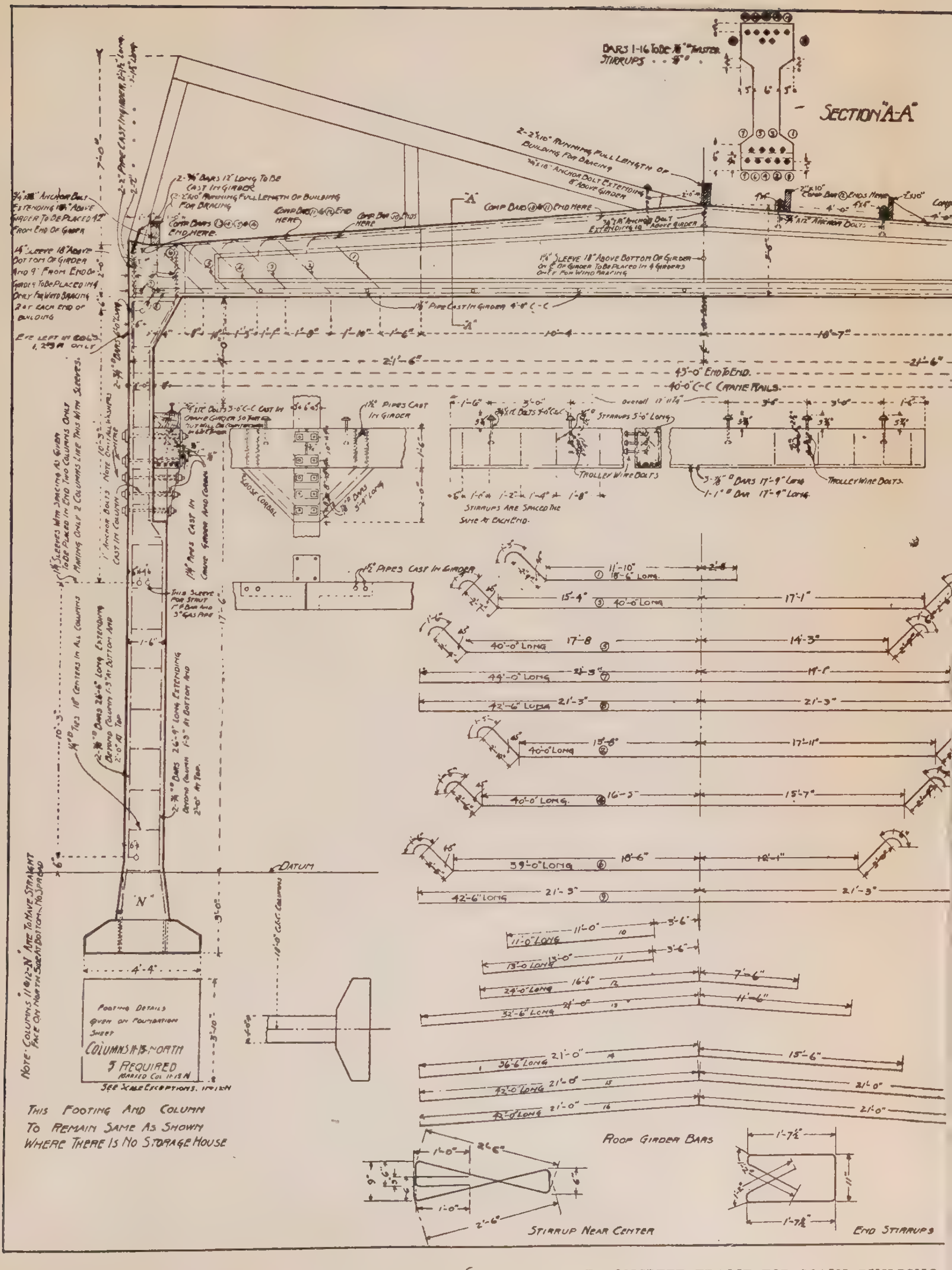
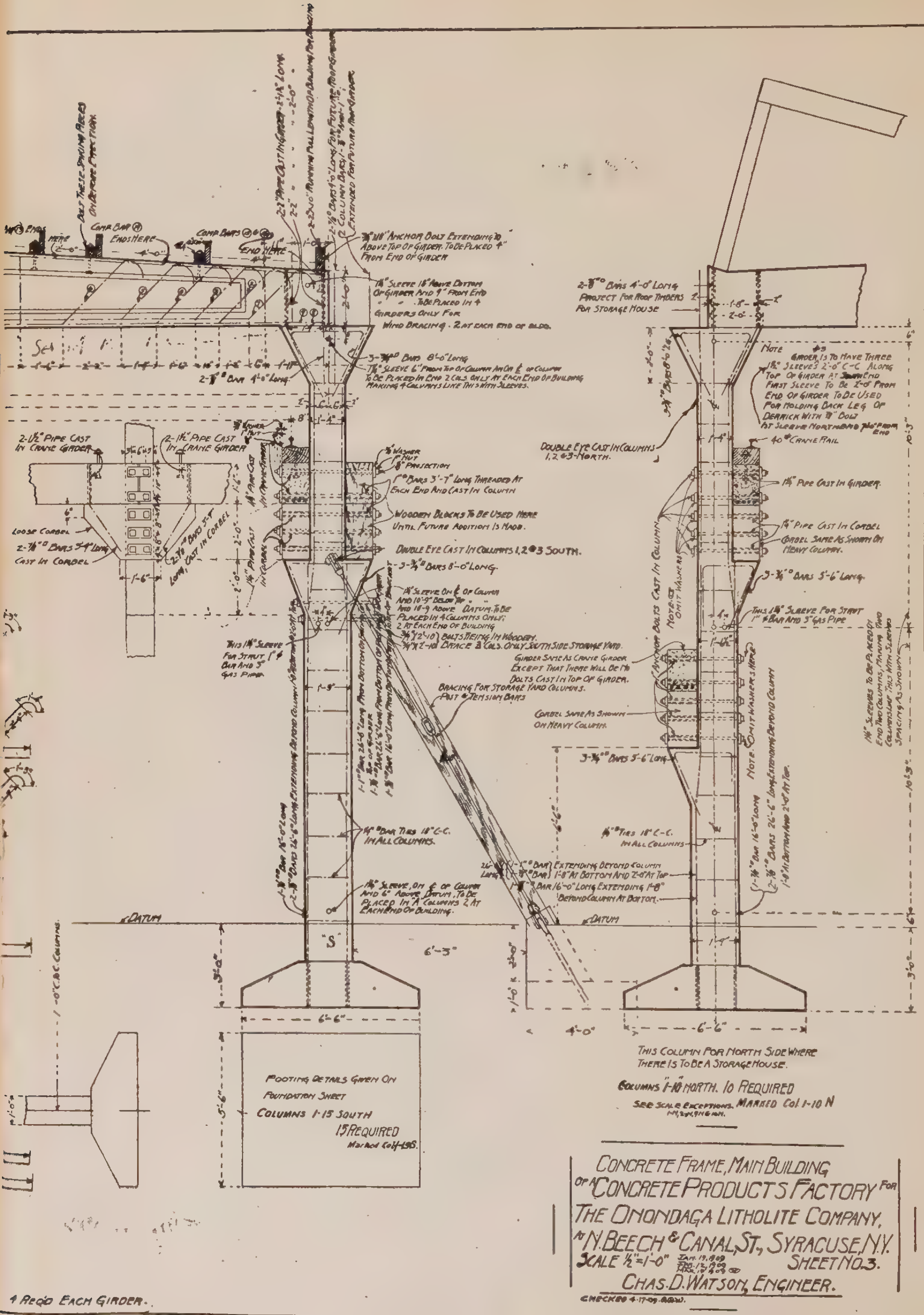


FIG. 6.—DETAILS OF CONCRETE FRAME FOR MAIN BUILDING



OF ONONDAGA LITHOLITE COMPANY, SYRACUSE, N. Y.

The author during the previous summer designed and supervised the erection of a unit concrete frame (Fig. 5) for a building somewhat similar to the above, in which the cost per cu. yd. was $20.00 erected. The difference in cost is doubtless due to the fact that the volume of concrete in the work was much smaller, and

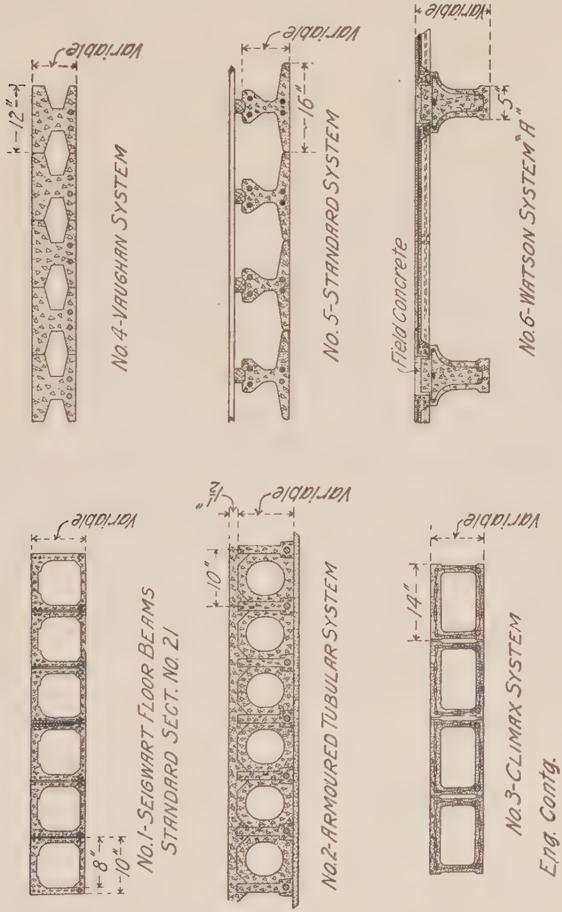


FIG. 8.—VARIOUS TYPES OF FLOOR SYSTEMS.

that the design was more complicated. The structural frame of this building (Fig 6 on Plate VI) consisted of columns, roof and crane girders, for a building 250 ft. long by 45 ft. wide, columns spaced 18 ft. on centers. On account of the unusual poor foundations, it was necessary to design this frame as an articulate

skeleton to prevent settlement from causing damage. It seemed best for this reason to make the frame of structural steel, or separately molded concrete members, as the cracking of the monolithic members might have proven serious.

Bids were taken on a steel frame design by the use of Bethlehem girder beam for roof girders and built-up columns. The actual cost of the frame erected in concrete was found to be almost identical with the lowest bid for structural steel frame, but the latter would not have been fireproof. The connection of the members in this structure were designed much like timber connections, *i. e.* bolting together.

Fig. 7 shows the various members before erection. The

TABLE II.—DETAIL COST OF STRUCTURAL CONCRETE FRAME PLANT OF THE ONONDAGA LITHOLITE COMPANY, SYRACUSE, N. Y., ERECTED IN 1909.

Reinforcement, bolts and wind bracing	$952.77
Lumber for forms	325.17
Concrete materials	488.63
General supplies	65.00
Labor of making and erecting	899.60
Power, interest, plant and other general expenses	250.00
Total cost	$2,981.37
Lowest bid for alternate design of steel frame	$3,000.00
Cubic yards of concrete	148
Cost per cu. yd.	$20.40

notable feature of this work is the size of the roof girders. These were designed with the expectation that the building would be constructed with a concrete roof, but it was finally decided to put on a temporary timber roof. All girders are 43 ft. over all with clear span of 40 ft., weighing about 6 tons. They were paneled to reduce weight, and make a more economical section. All members were made in wooden forms, and for the reason that the amount of material was comparatively small the concrete was all mixed and placed by hand.

Table II shows the detailed cost and comparison with the cost of steel frame construction.

The most extensive use of separately molded members has been in fireproof floor construction, where the members are made to take the place of terra cotta, or concrete fireproofing, and are

usually manufactured in an established factory, where all the economies of manufacturing can be had. Such members are usually made in as large units as are convenient to handle in the field, and all of comparatively long spans. The beam is designed, and the concrete molded in the most economical shape to give maximum strength with the minimum material.

There are several types of such floor construction now on the market in Europe and America. The more prominent systems are illustrated in Fig. 8 by a typical cross section.

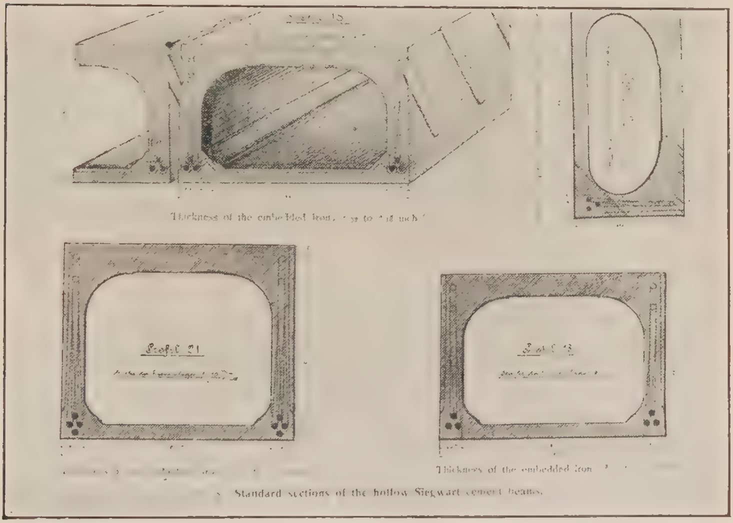


FIG. 9.—SIEGWART SYSTEM.

I. *Siegwart System.* This is designed by Hans Siegwart, an architect of Lucerne, Switzerland. Mr. Siegwart claims that there are over fifty factories throughout Europe making this type of floor, and that the Lucerne factory is manufacturing over a million feet per year. The only factory in America where these beams are made, known to the writer, is located at Montreal, Quebec.

Fig. 9 shows the standard section of the Siegwart floors. These sections are all of standard 10-in. width, the height and reinforcement being varied with the span and load. In a test on

FIG. 10.—STORAGE YARD. SIEGWART BEAMS WORKS OF DYCKERHOFF AND WIDMANN, CARLSRUHE, GERMANY.

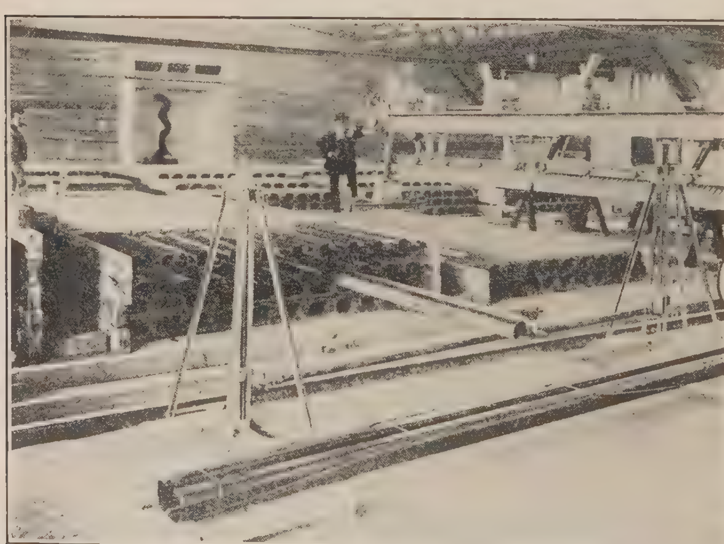


FIG. 11.—INTERIOR VIEW OF LUCERNE WORKS. SIEGWART SYSTEM.

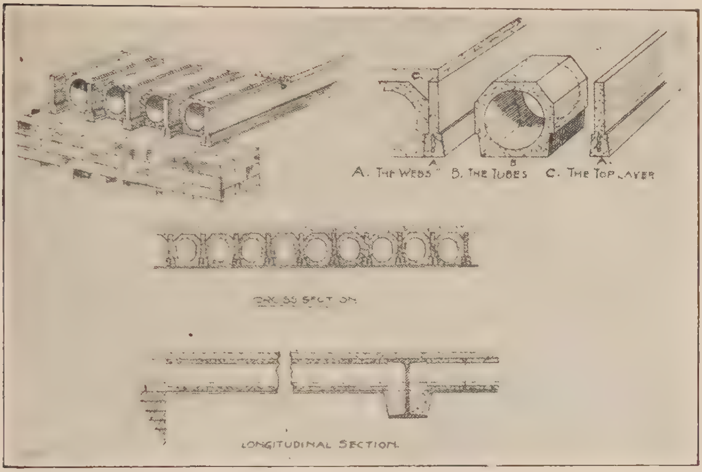


FIG. 12.—ARMOURED TUBULAR SYSTEM.

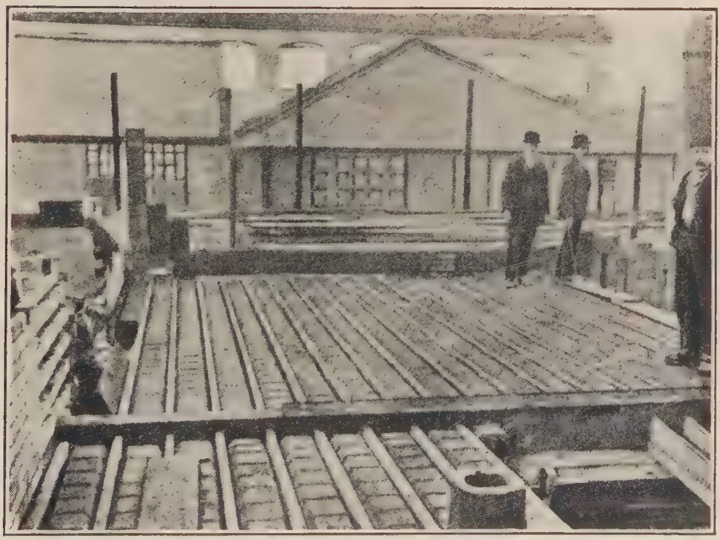
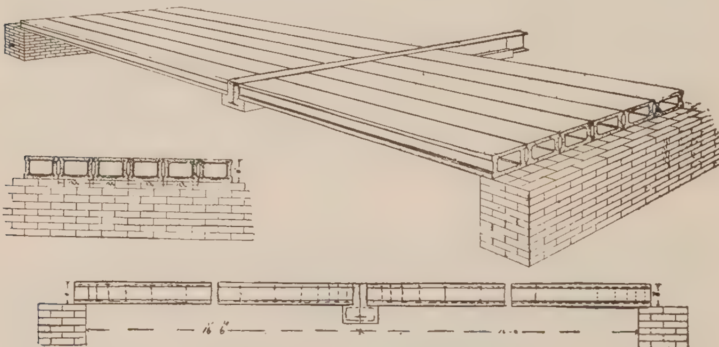


FIG. 13.—ARMOURED TUBULAR FLOORING IN PROCESS OF CONSTRUCTION, SPAN 22 FT.

one of these beams, standard section No. 21, reinforced to carry a live load of 150 lbs. per superficial ft. for a 16-ft. span, it carried over 600 lbs. per sq. ft., showing a sufficient factor of safety. The economy of weight between these beams and a monolithic floor is shown by comparing a slab designed to carry the same load with the same percentage of reinforcement. Such a floor would weigh at least 80 lbs. per sq. ft., whereas the Siegwart floor weighs but 40 lbs. per sq. ft., using the same working units for strength of materials. Fig. 10 shows the storage yard of one of their factories, which gives a better idea of the general design of the beam, which can easily be handled by hand



Hollow. Reinforced, Concrete Beams For Fireproof Floors.

FIG. 14.—CLIMAX SYSTEM.

as shown. Fig. 11 shows a nest of the beams in the factory, the cores and machine for cutting the beams.

The Siegwart Company claim their method to be much cheaper than monolithic floors. From quotations furnished by their Canadian Company the price in Montreal is quite a little less than the author's experience for monolithic floors in the same city, ranging from 17 to 26 cts. per sq. ft. erected, for various spans and loads.

2. *Armoured Tubular System.* This system is used extensively in England. A typical design is shown in Fig. 12, while Fig. 13 illustrates a floor in process of construction. Tests of a 14-ft. span show that the floors are very strong, although the amount of concrete is apparently no less than what would be

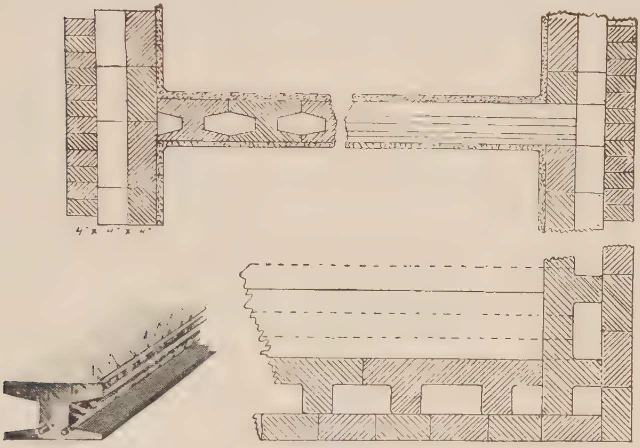
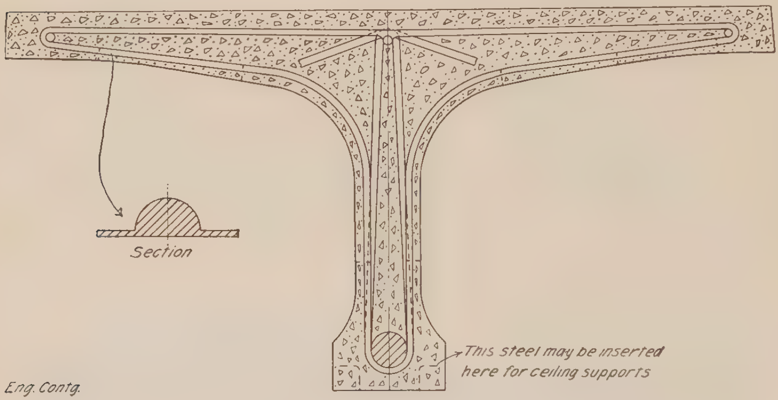


FIG. 15.—VAUGHAN SYSTEM.

FIG. 16.—VAUGHAN SYSTEM FLOOR IN PROCESS OF CONSTRUCTION.

required for an equal strength in a monolithic floor. The manufacturers of this floor claim the average selling price to be about 22 cts. per sq. ft.

3. *Climax System.* S. M. Randolph, Architect, Chicago, Ill., is the designer of this system (Fig. 14), which is marketed by the Climax Company of the same city. It is quite similar to the design of the Siegwart Beam, but having the space between



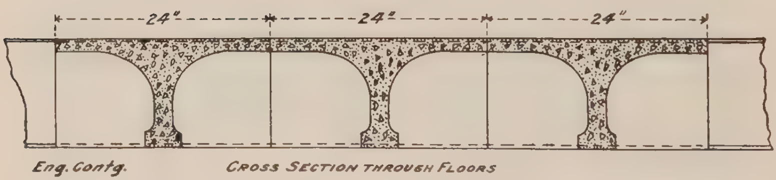


FIG. 17.—WATSON SYSTEM. T-BEAM TYPE OF FLOOR.

beams larger it provides better bond between the members. The author has no cost data on this particular system.

4. *Vaughan System.* Typical forms of this system, marketed by the Vaughan Company, Detroit, Mich., are shown in Fig. 15. In a test an 8 x 12 ins. beam on 14 ft. 6 ins. span sustained a total load of 586 lbs. per sq. ft. before breaking. Fig. 16 shows the method of placing these beams.

5. *Standard System.* This system was designed by C. F. Buente of Pittsburgh, Pa., and has been worked out for walls as

well as floors.* The amount of floors actually constructed with these beams is quite limited, and in such small areas as to be of no real value for comparative cost records.

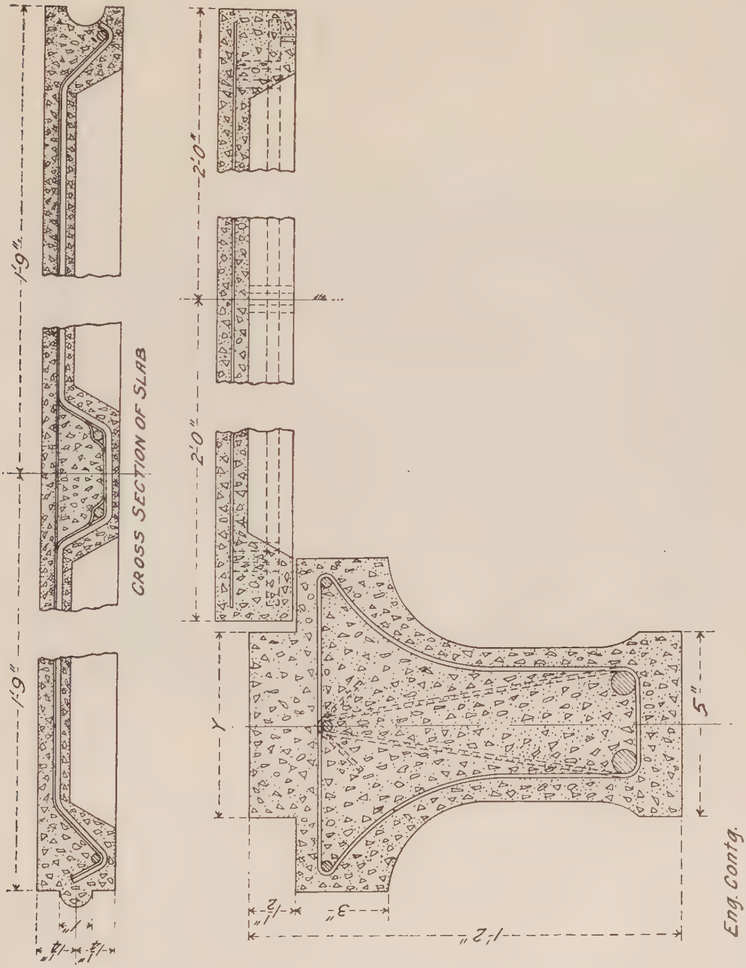


FIG. 18.—WATSON SYSTEM. BEAM AND SLAB TYPE OF FLOOR.

6. *Watson System.* Figs. 17 and 18 show the details and section of the types of floors for several buildings recently constructed by the Onondaga Litholite Company, Syracuse,

* See *Proceedings*, Vol. IV, p. 97.

N. Y. For long span and heavy loads the T sections (Fig. 17) are used, laid side by side. The width of the flange depends upon the space that beams are to fill, the load and span. For roofs and all floors having span less than 20 ft. and loaded less than 200 lbs. per sq. ft., the combination of a slab and T beam is used, the beams being spaced about 5 ft. on centers, as shown in Fig. 18. The slabs are then laid between the beams and grouted at the joints. This particular design has worked out

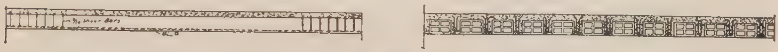
FIG. 19.—VIEW OF CEILING. BEAM AND SLAB TYPE OF FLOOR. WATSON SYSTEM.

very satisfactorily and economically in actual construction, as it allows of great variation of design, and diversity of finish. Suspended ceilings are easily attached if desired, but the members themselves look very nice when properly pointed and given a cement wash (Fig. 19). This particular floor illustrates admirably the economy of such construction. The beams are 22 ft. long, having about 19 ft. clear span, spaced 4 ft. 6 ins. center to center. The floor carries a load of 150 lbs. per sq. ft. and has been tested to 600 lbs. per sq. ft. The total dead weight of this floor is but 37 lbs. per sq. ft., and the weight of the steel 2¾ lbs. per sq. ft. If the amount of concrete was reduced to

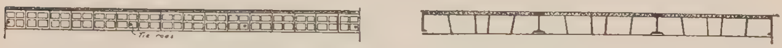
slab form it would be less than 3 ins. thick. It is doubtful if any designer would attempt to build a flat slab of this length

1. Flat Slab.

2. Standard Slab and Beam.



3. Concrete and Tile.



4. Terra Cotta and Concrete Top.

5. Unit Beam and Slab.

FIG. 20.—TYPES OF FLOOR CONSTRUCTION COMPARED IN TABLE III.

TABLE III.—RELATIVE DEAD LOADS AND WEIGHTS OF UNIT VS. PRESENT STANDARD FIREPROOF FLOOR CONSTRUCTION.

Span 16 ft.; Superimposed Load 150 lbs. per sq. ft.; Tension in Reinforcement 16,000 lbs. per sq. in.; Compression in Concrete 630 lbs. per sq. in.; Shear 50 lbs. per sq. in.

No.	Description.	Dead Load, per sq. ft.	Weight Reinforcement, per sq. ft.	Graphic Comparison.	
				Dead Load.	Weight of Reinforcement.
1.	Flat slab	96	3.75		
2.	Concrete and tile	72	2.77		
3.	Slab and beam ..	56	2.41		
4.	Terra cotta	55	5.4		
5.	Unit slab and beam	45	2.75		

to sustain the same load with less than twice this thickness with the same amount of reinforcement.

Fig. 20 shows a comparison of the dead loads and weights of reinforcement per sq. ft. of various monolithic floor systems now

most extensively used, with a floor similar to the one just described. The comparison is made for the same span and load using the same values for the strength of reinforcement and concrete. Without giving itemized costs of floors actually constructed, the writer has found it to vary from 15 to 30 cts. per sq. ft. erected, depending upon the various conditions of load, span and delivery. The average cost of steel fabricated is a little less than 2½ cts. per lb. in place, based on the present market value, showing that the cost of the concrete members vary from 50 cts.

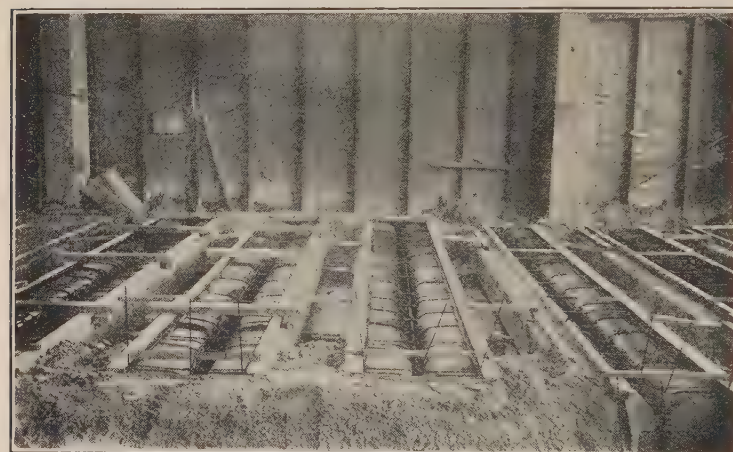


FIG. 21.—UNIT FRAME REINFORCEMENT FOR T-BEAMS IN MOLDS READY FOR CONCRETING.

to $1.00 per cu. ft., not including steel. This is very much greater than the cost of making and placing concrete blocks, and almost as great as for ornamental stone. This would indicate that a large reduction could be expected as the methods of manufacture are perfected, but even at this price they compare quite favorably with cost of monolithic floors for same spans and loads.

Fig. 21 shows the method of making the beams, the unit frames used for reinforcement being in place.

Fig. 22 shows a slab and the reinforcement for same. These slabs are made on edge in steel forms, each form containing 350 sq. ft. of slab. The concrete is driven into place

FIG. 22.—SLAB SHOWING POSITION UNIT FRAME REINFORCEMENT.

FIG. 23.—METHOD OF HANDLING FLOOR MEMBERS.

FIG. 24.—VIEW OF CEILING BEFORE POINTING AND GROUTING.

FIG. 25.—INTERIOR VIEW OF COMPLETED STRUCTURE.

TABLE IV.—DETAILED COST OF STORAGE WAREHOUSE SUPERSTRUCTURE, SYRACUSE COLD STORAGE COMPANY.

(Erected 1909, using unit concrete floor and roof members.)

Building 78 ft. × 78 ft., steel frame fireproofed, having basement, six storage floors and concrete roof. Floors designed for 375 lbs. per sq. ft. total load. Total area of floors, 40,432 sq. ft.; volume, 424,480 cu. ft.

	Classification of Work.	Quantities.	Cost.	Total Cost.	Cost per yd.	Cost per lb.	Cost per sq. ft.	Cost per cu. ft.
Concrete Floors.	Concrete materials in floors: cement at $1.40 bbl., stone at $1.10 ton	373 yds.	$1,156.30		$3.10		.028	
	Reinforcing steel in floors, f.o.b. shop	105,810	1,454.40			.014	.036	
	Labor fabricating reinforcement		317.43			.003	.008	
	Labor making floor sections and roof		2,605.69				.064	
	Labor erecting members		1,650.10				.040	
	Hauling and freight on members from factory (2 miles)		382.57				.008	
	Power, erection tools and supplies		217.40				.005	
	Fixed factory charges, including power, interest and depreciation		500.00				.012	
	Total for floors in place, not including pointing or grouting			$8,283.89			.205	.0195
Structural Frame and Fireproofing.	Structural steel erected	250,000	$7,050.00			.028		
	Materials for concreting floors and fireproofing steel		244.84					
	Labor pointing and concreting floors and fireproofing steel		1,149.00					
	Lumber for forms used in fireproofing steel		150.00					
	Freight, delivery and cartage on field materials		50.00					
	Tools, power and supplies		100.00					
	Total for frame and fireproofing			$8,743.84			.216	.0206
	Engineering and superintendence		798.53				.019	.001
	Total for floors, frame and fireproofing			$17,826.26			44	.041
General.	Brick curtain walls, stairs, trim, felt and gravel roof, and all other work to complete superstructure		$6,904.76				.17	.016
	Total cost of superstructure			$24,731.02			.61	.057

and around the reinforcement by means of a special jarring or vibrating machine.*

In the construction of several buildings for the Syracuse Cold Storage Company, the T section of beam was used for all floors, and the beam and slab construction for the roof. This was done on account of the excessive load the floor had to sustain, being 300 lbs. per sq. ft., and in no case was the floor allowed to touch the wall. One of these buildings, the main

FIG. 26.—PLACING OF ROOF SLABS.

storage warehouse, is an excellent illustration that this type of floor construction in conjunction with the reinforced or fireproofed steel frame, is not only practical for buildings of considerable height, but economical as well. This building was a six story and basement warehouse 78 ft. square. It was originally designed for mill construction, but alternate bids were taken for monolithic concrete, and a steel frame fireproofed, using sectional floors. The bid for the latter construction was considerably lower, in fact both bids were less than the cost of the mill construction. On account of time of delivery, and cer-

* See *Proceedings*, Vol. IV, p. 112

tain insulation details it was found impractical to design the steel work as ordinarily is done for such a structure, *i. e.*, using sufficient steel to sustain the dead load during the erection, and so that with the addition of the field concrete the member would be strong enough to carry the live load with a proper factor of safety. The steel work was, therefore, designed as for the use of terra cotta fireproofing.

In order to get a flat ceiling the supporting girders were all made of Bethlehem special girder beams. The concrete floor sections for this one building were transported by rail to the site, but for the other buildings they were delivered by team, and the cost was found to be about the same. The members were unloaded by means of a boom attached to the frame, power being furnished by a gasoline hoist. They were distributed about the building and set in place by means of chain hoists on portable I beam trolleys (Fig. 23). The top flange of one beam in each panel was coped to allow the beams to enter, and they were slid into position on the lower flange, wedged up, pointed underneath, the projecting reinforcement tied over the top flanges, and the spaces between the ends and edges grouted in solid.

Fig. 24 shows a view of the ceiling before pointing and grouting, and Fig. 25 an interior view of the completed structure.

The roof was constructed of beams and slabs, being of the design previously described for light floor construction (Fig. 26). The roof beams, or rafters, were supported by concreting around the lower flanges of the girders, and slope of the roof obtained by placing this concrete on a grade.

As to the vital question of cost, Table IV gives the cost of the floors and complete structural frame fireproofed, and is presented with the belief that it is a record for a fireproof building of this size designed to carry equal loads.

It must be remembered that the building was designed for comparatively heavy loads, each floor except the top had to carry 300 lbs. per sq. ft. superimposed. Tests were made on sections at regular intervals during manufacture and in no case did a beam fail, loaded with less than 900 lbs. per sq. ft., tested at an age of 21 days. The spans averaged about 15 ft. 3 ins. and the depth of all floors was 12 ins. The dead weight, not including the insulation and its protection, was 40 lbs. per sq. ft. The cost

of the floors as shown in Table II was found to be 20.5 cts. per sq. ft. erected. The cost of the steel frame and fireproofing about 21.5 cts. per sq. ft. The cost of engineering and superintendence about .02 cts., which should be proportioned about equally between the floors and frame, making a total cost of the floors 21.5 cts. and the frame 22.5 cts. per sq. ft., or a total of only 44 cts. per sq. ft., or 4 cts. per cu. ft. of volume for both frame and floor.

It should be noted that this sq. ft. measurement is the net floor area for the six floors and basement computed by the inside dimensions of the building. The cost of the balance of the work to finish the superstructure, such as curtain walls, gravel roof, trims, stairs, but no heating and plumbing, brought the total cost of the superstructure for all work above the basement floor level up to 5.7 cts. per cu. ft.

The cost of the 2 in. granolithic wearing surface, on the floors, the plastering of the side walls to protect the insulation is not included in this cost, as it properly belongs to the insulation contract, since the floor members are usually made with a smooth wearing surface and in this particular case the cost of preparing the floor for the insulation equaled the cost of providing the usual finished surface.

On the same basis of costs found to obtain on this building it can be shown that a building of equal size designed to carry the same loads, but in which the peculiar conditions required in cold storage warehouses are not required, and designing the frame as the usual reinforced concrete structural steel frame is designed, could have been built for 57 cts. per sq. ft., or 5.5 cts. per cu. ft.

The various advantages of such construction as outlined in the beginning of this paper were well demonstrated in this building. In regard to speed of erection, it was found that four men and one engineer could unload and place about 1,500 sq. ft. of floors in an eight-hour day, Union iron workers being used for this work and paid at the rate of 50 cts. per hour. The building was found to be quite as rigid as any steel frame building with terra cotta or concrete floors and a section of floor was altered to make room for a scale pit on the ground floor in a very short time and at a small cost.

DISCUSSION.

Mr. L. J. Mensch.—Mr. Watson stated that the cost of the floor was 19½ cts. per sq. ft. He did not include any finishing nor plastering, so that figure is rather misleading. **Mr. Mensch.**

Mr. Leonard C. Wason.—I would like to ask Mr. Watson if he had any difficulty in getting smooth edges and a good finish and if there is any damage to the edges of the beams, slabs, etc., in handling. **Mr. Wason.**

Mr. Charles D. Watson.—A top dressing was placed, but owing to the fact that the insulation came on top it was only about ½ in. thick and was flushed with a broom. We found it cost nearly as much as 1½ ins. of top dressing without finish. **Mr. Watson.**

We had very little trouble with damage to the edges in handling the beams, although, as explained, this warehouse did not require any particular care. In the other building we were careful because everything was exposed and had to be given a coat of paint afterwards.

Mr. E. G. Perrot.—I would like to ask Mr. Watson whether the factory cost is given or is a profit included? **Mr. Perrot.**

Mr. Watson.—No profit is included. We calculated that interest on the plant amounted to 10 per cent., the engineering charge at 8 per cent. The 19½ cts. covers the exact cost including fixed charges, that is, the cost of the plant, rental, interest, depreciation and all the other items that should be included in such cost. I do not contend that 19½ cts. sets a very low price. Of course, many concrete floors are built for that price. The one thing I wish to call attention to is that the combination of a steel frame and concrete floor worked out remarkably cheap. **Mr. Watson.**

Mr. Robert A. Cummings.—I would like to add my testimony of a similar experience to that of Mr. Watson. During the past year I have put up two industrial plants in the South. I can say, without going into details, that the monolithic construction, which I have used for a good many years, will not compare in economy with the separately molded members for one story buildings. **Mr. Cummings**

Mr. Cummings. In reference to figures given in Table I, comparing our actual labor cost without engineering charges, we succeeded in putting up our work for about 10 per cent. of what Mr. Pratt did. For instance, we placed the reinforcement in our beams for 5 per cent. of the total labor cost. The reinforcement in units, delivered on the work, cost $1.34 per cu. yd., and the labor cost for placing reinforcement was 2 cts. per cu. yd. of concrete. On the slab work the material cost $2.50 and the labor about one per cent., or 27 cts. a ton. I desire to emphasize these statements because it has been my contention for the last 7 or 8 years that the only proper method in using reinforcement in concrete work is to follow the footsteps of the structural steel engineer and fabricate the reinforcement at the factory or build the members there. I abandoned the use of loose rods many years ago. I made a full and complete demonstration last year on buildings that cost over $250,000, of the advantages to be derived from unit construction when carefully designed. We found that the structural steel operators put in beams just about twice as fast as an ordinary laborer. The fact is they put them in much faster than we could make them which necessitated laying them off about 3 days a week.

REPORT OF COMMITTEE ON EXTERIOR TREATMENT OF CONCRETE SURFACES.

By L. C. Wason, Chairman.

The Committee submits herewith a progress report not with the idea that it is perfect or complete but with the strong desire that it form a basis for discussion and that from the discussion a more complete and concise statement of the subject can be prepared and specifications which will enable anyone fairly experienced in the art to do good work.

Plan and Scope.

A synopsis of the ground the Committee is proposing to cover is given below. It is not assumed that this synopsis is perfect and any subjects which should properly be treated by this Committee and which have been omitted, will be added to this synopsis.

I. Effect of Material and Workmanship on Surface.

- (*a*) Cement.
- (*b*) Sand.
- (*c*) Stone.
- (*d*) Foreign matter, active or inert (glass, oil, glue).
- (*e*) Water.
- (*f*) Pigments.
- (*g*) Effect of molds.
- (*h*) Method of mixing and placing.
- (*i*) Treatment while hardening.

II. Removal of Surface in Various Ways.

- (*a*) Unskilled labor. Picking, scraping, rubbing, whether hard or green.
- (*b*) Skilled labor. Crandall, bush hammer, tooth tool, chisel, set, lathe.
- (*c*) Sand blast (size of nozzle).
- (*d*) Chemical treatment (kind, strength, method).
- (*e*) Age of cement when cut or treated.
- (*f*) Tools, kind, quality, temper.

(*g*) Effect of cutting on impermeability.
(*h*) Effect of cutting on durability.
(*i*) Effect of cutting on collection of dirt.
(*j*) Advantages and disadvantages of certain treatments.
(*k*) Photographs.

III. Coating Surfaces in Various Ways.

(*a*) Texture and condition of masonry surface to be covered. (Masonry includes brick, terra cotta, stone, concrete, mortar, plaster.)
(*b*) Metal lath, kinds, method of erection.
(*c*) Preparation of base to obtain a bond.
(*d*) Material, cement, sand, lime, pigments.
(*e*) Mixing.
(*f*) Placing, number of coats, and treatment of each, workmanship, texture.
(*g*) Joints.
(*h*) Washes, cement, etc.
(*i*) Paint.
(*j*) Enamel.
(*k*) Durability.
(*l*) Photographs.

IV. Ornamental Work. Possibilities and Limitations of Surface.

(*a*) Cast concrete.
(*b*) Cast mortar.
(*c*) Plastered mortar.
(*d*) Kinds of molds. Wood, plaster, iron, glue, sand (plain or treated), clay, sanded paraffine.

V. Waterproofing.

(*a*) Necessity.
(*b*) Mixed in concrete, either as a powder or a liquid.
(*c*) Method of incorporation.
(*d*) Surface treatment where the compound is colorless.
(*e*) Surface treatment where the compound changes the color of the surface.
(*f*) Durability of each material.
(*g*) Effectiveness of each material.
(*h*) Preparation and condition of surface to receive each of above treatments.
(*i*) Mortar.

VI. Limitations, Defects, Blemishes of Various Sorts and Remedies.

(*a*) Range of colors.
(*b*) Variation of color due to workmanship and weather.
(*c*) Craze cracks, checking.
(*d*) Expansion and contraction cracks.
(*e*) Irregular size (bulging of molds).
(*f*) Mortar and stone at horizontal joint between days' work in concrete wall.
(*g*) Patches are a darker color.
(*h*) Efflorescence, cause and remedy.
(*i*) Porosity, cause and remedy.
(*j*) Frozen surfaces and frozen body.
(*k*) Softness of surface.
(*l*) Dusting.

VII. Specifications to obtain all the treatments and results of each sub-heading, No. 1, 2, 3, 4, 5.

VIII. Costs.

Exact and relative cost of each method, and manner of estimating cost of materials and labor.

I. EFFECT OF MATERIAL AND WORKMANSHIP ON SURFACE.

This heading pre-supposes that the surface will be treated in some way so as to remove the surface coat, otherwise the ingredients of the mortar or concrete would make little difference.

(*a*) *Cement.*—The color of the surface is largely that of the cement which is used. Although there is some difference in the shade of gray of standard Portland cements, the difference is so slight that with very few exceptions no thought need be given to the color of cement. There are also some white cements on the market which give a very pleasing treatment to the finished surface. Consideration should be given to some extent to seasoning, as a well seasoned cement is less likely to cause craze cracking or shrinkage cracks than one which is fresh. The subject of fineness of grinding is of less importance but is worthy of some consideration.

(*b*) *Sand.*—If the surface is tooled or scrubbed particles of sand will be exposed to view and their color will have an important influence upon that of the surface. Their size will also have an influence upon the texture. A sand with large round grains such as is found on the sea coast in places, the grains being practically of one size, cannot be used in as rich a mixture as sand of variable size and angular grains, because the round grains will rub from the surface with considerable readiness if the mixture is 1 to 2 or leaner, and as the grains in the first named sand are large they have more influence upon the color than sand of variable sizes. The coarse Plum Island sand used in Boston and vicinity has uniform sized grains and is of a yellow color, and work done with it has the appearance of being iron stained. A light gray or white quartz sand will lighten up the color of the mortar very materially so that it would appear that some pigment had been used with the cement. Stone dust makes an excellent sand and when of a grayish color can scarcely be distinguished from that of the cement, thus giving a uniform appearance. Quite a variety of colors and textures can be obtained by care in selecting the sand, either natural or stone dust, of variable sized grains, ranging from that which will pass a 30 mesh sieve to that which would just barely be rejected upon a ¼ in. sieve.

(*c*) *Stone.*—The stone, still more than the sand, can be used to vary the appearance of the finished surface on account of its larger size and ease with which it can be cleaned of cement when the latter is still green. It is possible to get a very wide range of colors in stone and one color can be used or two or more can be mixed together and give very pleasing effects, the size ranging from rejection of the ¼ in. sieve to that which would just pass a 2 in. ring. Contrasting the angularity of broken stone with the round and smoother surfaces of gravel, gives effects which are still more varied than with quarry stone, and are just as durable so far as strength and waterproofness are concerned.

(*d*) *Foreign Matter.*—It is also possible to get some pleasing effects by the introduction of foreign matter such as broken brick, glass, fragments of metal like copper, brass, even nails are sometimes used, but the rust and stain from the iron nails is unsightly. Sometimes ores, such as the green ore of copper have

been used for producing certain effects. Oil, glue, lime, have also been introduced at times for certain purposes. In one instance the following mixture was used: To every barrel of cement was added 4 lbs. of salt and 20 lbs. of quicklime slacked for one week, passed through a fine screen, 4 lbs. of lampblack and 1 lb. of linseed oil. In preparing this the lime was first slacked and while yet hot the salt in solution together with the lampblack and oil, were added and all stirred thoroughly together, the mixture then being passed through a fine screen into vats and allowed to stand for one week or longer before using. The proportion of aggregates to the cement was 6 to 1, the stone being a mixture of dark blue trap and white marble.

(*e*) *Water.*—Water has its influence on the appearance of the surface in several ways. The amount of water has an influence on the density. When the mixture is quite dry it is impossible to compact materials well, and the resulting mortar or concrete is porous. If a sufficient amount of water is used to produce a plastic mix the appearance is dense and uniform, while a large excess of water brings the fine particles to the surface and produces a little different texture from plastic. Moreover, the quantity of water affects somewhat the time of set of the cement and thereby to some extent the color.

(*f*) *Pigments.*—Coloring matter of various kinds can be added to the mixture. Those of a vegetable origin are not permanent because they are likely to be acted upon chemically by the ingredients of the cement. Only mineral colors should be used. The amount which can be safely used is small, owing to the danger of impairing the strength of the resulting mortar. Five per cent. by weight to that of the cement should be the limit, beyond which the impairment of strength is too great to justify a larger amount. Even this amount of certain colors which differ little from that of the cement like yellows and reds, do not produce a marked change from that of the neat cement. Lampblack is the principal ingredient used for darkening which, on account of its strong contrast and the fineness of its particles produces a strong contrast with a moderate amount. For lightening the color somewhat, lime is the best material to use. Coloring matters can be used in either a dry form or as a paste. It will generally be found

most convenient for mixing to use the dry form, thoroughly mixing it with dry mortar before the addition of any water.

(*g*) *Molds.*—Molds also have an influence upon the appearance to some extent. With rigid materials like metal or wood there is a tendency for the coarsest particles to come to the surface, and unless this is overcome by spading or proper manipulation the surface is likely to be rough and porous, and if the stone is pushed too far back a mortar face is obtained. With rigid molds which are non-absorbent, the surface is likely to be of a watery appearance and after hardening will have small holes in its surface where drops of water stood and later evaporated. Porous molds, such as sand or various combinations of sand and other substances, treated or untreated with chemicals, all produce a similar effect, namely a dense cement surface, as the cement is brought to the surface by the excess water which is absorbed by the molds. However, this type of mold does not remove cement from the mortar and its surface of contact is not bonded to the casting by the excess of cement which comes to the surface. This excess of cement on the surface is liable to cause hair or map cracks and in large specimens is subject to shrinkage more than with molds of other material. If the mold is not filled by continuous pouring an unsightly line impossible to conceal later is left where work stopped.

(*h*) *Mixing and Placing.*—On account of map cracking and shrinking it is not wise to mix mortar richer than one part cement to two parts sand, and for freedom from these two defects it is frequently better to mix it as lean as one to four. Stone in proper proportions can be added to the mortar to get the desired textures. Thorough uniform mixing and quick placing are desirable features. The aggregates should be graded with the utmost care to get a maximum density. A concrete whose surface has to be removed should be so made that it will have an absorption of not more than 5 per cent. by weight. These subjects have been so well covered in the past contributions to this Association that detailed treatment is here unnecessary.

(*i*) *Treatment While Hardening.*—The appearance can be modified somewhat by the treatment of the surface while hardening. If it is allowed to dry rapidly it will be of a lighter color

than if kept damp and cool and allowed to dry slowly, also, the former surface will be more dusty than the latter.

II. Removal of Surface in Various Ways.

(*a*) *Unskilled Labor. Picking, Scraping, Rubbing.*—A variety of treatment can be given to the surface by the use of unskilled labor. Taking such tools as a hand pick with a single point or a pick with a face of two inches with a series of points upon it, the surface may be scaled from the concrete, entirely removing any marks of the mold or any stains from a coating placed upon the surface of the mold to prevent adhesion of the mortar, leaving the surface below of a natural cement color and exposing the sand grains and the stone of which the concrete was composed. The cost varies considerably with the age of the cement when the picking is done. When done at the age of three or four days a laborer can cover four to five times the area he can do when the cement is two or more weeks old. The texture, however, differs. Because a larger amount of material is scaled off when the material is quite green and scaled off to varying depths, and because some particles of stone are chipped out of the surface, the texture is much coarser than when done after the cement has become hard. Under the latter condition the surface has a fine texture and is quite uniform. A little variety can be obtained by the method in which the blow in picking is applied. By striking a perpendicular blow there is no resulting mark left on the surface by the tool, whereas with a glancing blow lines are left, and these can be made to show all parallel to one another or at various angles, and thus a little variety to the texture can be thereby given.

Another way of treating with unskilled labor is by scrubbing with water and stiff brushes, either bristle or wire brushes, while the mortar is still quite green. This removes the excess cement from the surface, obliterates the marks of the molds, and washes considerable of the cement off the surface of the aggregates, so that they appear cleaner, sometimes as clean as freshly-broken stone, and thereby obtaining a bright and pleasing effect. It is common also, in this method, to use an acid which will

attack green cement rapidly and eat it from the surface of the aggregates. This type of treatment is used usually during the first forty-eight hours after the cement has been cast. After this age the cement resists the scrubbing and acid process to such an extent that it becomes expensive, and the best results are not obtained.

Nitric, muriatic and sulphuric acids and soap in various strengths up to the undiluted have been tried, and experience is that these agents are impracticable for the removal of vertical surfaces of *good* concrete thoroughly hardened, the action being so slow and attended with so much difficulty that hammering of one sort or another is cheaper.

Great care must be taken in successive casting to prevent marks showing (after scrubbing) where the new and old work join. The practical operation is to finish casting on some line in the building, although in certain architectural treatments this stratification is not objectionable. When it is proposed to scrub the surface of the concrete before it is more than twenty-four hours old, it is necessary to design the forms specially with the idea of being promptly removed without damage to the rest of the structure. This will usually save lumber, but designing for quick removal will usually add to the labor an amount sufficient to offset this. Moreover, arranging to make possible the removal of forms at certain points of the work does not necessarily get the maximum efficiency from the mixing plant, as the quantity of work may not be such as to run the plant at full efficiency for a day.

Another way of treating flat surfaces is by rubbing with pieces of limestone, water and sand, cutting away the mortar and surface of the stone, so as to expose the full cross section of the stone. This is done when the mortar is three or four days old, and is done only with the softer stones, such as marbles. This type of finish is usually known as terrazzo.

(*b*) *Skilled Labor.*—The surface of concrete after it has become hard can be cut as natural stone would be cut, but this should be done by men who are experienced in stone cutting, and when treated in this way textures similar in character to those of natural stone can be obtained, in fact, the crandall, bush ham-

mer, tooth tool, chisel and set can be used with such effect that at a short distance the appearance is identical with natural stone.

By cutting the material when green, it is impossible to get sharp corners. The round corners which are common in concrete are generally inartistic and crude in appearance. By allowing the material to become quite hard and using proper care, as sharp corners can be obtained as with natural soft stone such as limestone. It will thus be seen that the results to be accomplished have a controlling influence over methods to be used. In this way additions have been made of concrete to old buildings of natural stone with such a perfect matching of texture and color that it is impossible to tell the difference at 8 ft. distance.

It has been the experience of some engineers that just as cheap results can be obtained from bush hammering by common labor as by skilled. This, however, should be qualified again by the result to be obtained. On large surfaces where a coarse general treatment is desired and where the observer cannot get close to the surface, it can be tooled by common laborers when the material is quite soft. If, however, the observer can come within a few feet of the surface the above described treatment is not as good as cutting by skilled labor after material has become thoroughly set. A treatment which has been used to a limited extent has been splitting blocks which have been cast in a plane so as to obtain a natural fracture, and a similar effect can be obtained by breaking off pieces of the surface by a stone set to obtain a natural fracture. In this manner the natural fracture of stone is more closely imitated, but as the whole general treatment is so unnatural to a cast material it is an inartistic treatment and is not recommended.

Still another way is by cutting in a lathe such objects as columns. After the cement has well set the stone can be cut in two without pulling out from the mortar. Thus the center of the stone can be exposed which is of large cross section relatively to the sand in the mortar, and a more stony appearance obtained. If the stone itself was capable of taking a polish a fairly smooth treatment can be given it by rubbing it down in a lathe after turning. Mortar itself will not polish.

(*c*) *Sand Blast.*—A finish can be obtained somewhat similar

to that of scraping by means of sand blast. It is important to have the right sort of a nozzle, however, for this kind of work, and an exceedingly hard sand must be used, preferably that which has angular grains. A ½ in. diameter nozzle would produce very unsatisfactory results, because if an excess of cement came to the surface at one spot or on an edge as a joint between boards its hardness would resist the cutting of the sand while softer portions on either side would be removed, thus emphasizing the ridge. Similarly a soft spot formed by a wide crack where the cement all ran out leaving the sand behind would be cut deeper by the large nozzle. Experience has shown that a nozzle not over ⅛ in. diameter should be used so that it can be localized on small spots and that it must be held within a few inches of the surface to be cut if there is any variation in the density or hardness of the surface.

This method leaves the stone cleaner than with scrubbing and acid treatments.

Again, the age of the mortar has a large influence upon the cost of the cutting and upon the texture of the surface. Good and economical results can be obtained when the cement is between ten and fourteen days old. It requires a fairly large job to justify the cost of setting up and operating a sand blast plant. Various building cleaning companies have portable outfits which are admirably adapted for this kind of work which can be obtained in all large cities.

(*d*) *Chemical Treatment.*—When the surface is chemically treated the materials used are usually commercial hydrochloric or sulphuric acid. The amount of dilution must be determined by experiment and will vary with the age of the concrete. The older the cement the stronger must the solution be. For cement which is about two weeks old ordinary commercial acid should be diluted with three parts of water. When but a few days old a dilution of one part acid to five or six of water will be sufficient. A mixture of the two acids will produce stronger action than the use of one alone. They also produce a vapor which will soften the surface when exposed to it in a confined chamber and permit removal of the surface with very little scrubbing. After the scrubbing is completed great care must be used to

remove all traces of acid, otherwise there will be permanent discoloration of the surface.

(*f*) *Tools. Kind, Quality, Temper.*—A new type of brush for rubbing or scrubbing green concrete surfaces which has proved very efficient in actual work is composed of ordinary wire mesh, such as fly screen, and is made by clamping together a sufficient number of sheets of wire, all of equal size, so that the exposed or rubbing edge will be at least 4 in. wide. Such a brush has proved much more effective and cheaper than the ordinary wire brush.

(*g*) *Effect of Cutting on Impermeability.*—The waterproofness of concrete depends upon the density of the mortar. In the packing of mortar on surfaces which are to be exposed, greater care is usually taken in producing a dense uniform surface which would show a good appearance than in the packing of the whole mass of materials in the back. Therefore, before cutting, there is usually a dense skin of rich mortar on the surface which is practically impervious to moisture. When this is removed by any process the interior is more likely to absorb moisture than before. In one particular job where the aggregate was composed of coral sand and coral stone which was very porous like cinders or blast furnace slag, after picking the concrete permitted water to drive straight through a 12-in. wall from a driving rain, whereas the wall previous to tooling was practically impervious. With a dense stone and quartz sand, a rich mixture, plastic consistency, well packed, a wall may be as impermeable after treatment as before. These facts are sometimes overlooked and cause unexpected and unpleasant results.

(*h*) *Effect of Cutting on Durability.*—A wall which will absorb and hold moisture is liable to disintegrate ultimately by the action of frost. If it is impervious to moisture the action of frost is merely an attack upon the surface and is very much slower, being practically the same as on any surface of a solid natural stone. Therefore, in a cold climate, cutting off a skin to expose a porous mass is likely to somewhat impair the durability.

(*i*) *Effect of Cutting on Collection of Dirt.*—It is common sense to see that roughening the surface of the cement is going to permit collection of dirt and dust blowing in the streets much

faster than a surface which is smooth and dense. However, as dirt and dust is usually so like the color of the cement itself it does not produce an objectionable change, and these very fine particles can lodge in the pores of the concrete and assist in rendering them more impermeable. It is only where smoke is thrown out in large volumes that the smoothness of the surface must be considered to resist a change of color.

(*k*) *Photographs.*

III. COATING SURFACES IN VARIOUS WAYS.

(*a*) *Texture and Condition of Masonry Surface to be Covered.*—Masonry as above used includes brick, terra cotta, natural stone, concrete, mortar and plaster. The covering coat must bond to the solid material of the back and not to the dust or dirt particles on the surface and should be sufficiently substantial to hold the covering. If it is not substantial and rigid and contains cracks the surface covering is pretty sure to crack over the cracks in the back.

(*b*) *Metal Lath. Kinds, Method of Erection.*—For outdoor purposes, it is best to use galvanized metal lath. There are various kinds, woven, welded, expanded, any one of which can be used. That having a large cross section of metal and being heavily coated with galvanizing material is likely to be the most durable, if moisture should penetrate through the plastering to this material. It should be thoroughly tied to furring at intervals not exceeding 16 ins. with galvanized wire. The furring should leave sufficient space for the mortar to push through the mesh and clinch without interference from the backing to which the furring is attached.

(*c*) *Preparation of Base to Obtain a Bond.*—The texture should be as rough as possible with recesses in the surface which will support and key on a coating which is applied, and this surface should be free from dust and dirt which would prevent the bond of union. Before coating the surface the base should be throughly saturated with water so as to avoid suction of moisture from the covering coat which would impair its strength and durability.

(*d*) *Material. Cement, Sand, Lime, Pigments.*—Materials used are cement, sand of a quality previously mentioned, also lime and pigments of various kinds and quantity.

(*e*) *Mixing.*—The mixing must be thoroughly done and the amount of water used is less than with mortars or concrete packed in molds, as otherwise the mortar would run off the lath.

(*f*) *Placing.*—The first or scratch coat should be composed of one part Portland cement, three parts sand and one-half part hair putty. This hair putty shall consist of long cattle hair or fiber, thoroughly worked into good lime putty. The second coat should be composed of one part Portland cement, two and one-half parts of sand and with not over 5 per cent. lime putty. The third or finishing coat to consist of one part Portland cement to two parts of sand, with not more than 5 per cent. of lime putty. (To this finishing coat may be added pebbles or other non-combustible material as may be desired to obtain a variation in the finished appearance.) Where a total thickness of not more than one inch is required, it is practicable to apply it in two coats, *i. e.*, omitting the second coat above specified. In all cases, one coat should follow the previous one as soon as it has sufficiently set to allow of so doing. This will guarantee a bond of the two applications. The finished appearance may be varied by the materials used, both as regards color and size, by the mechanical method of applying or finishing, or by a combination of any of these methods.

(*g*) *Joints.*—Plastered surfaces are more subject to shrinkage cracks than monolithic work because a richer mixture is used and the thinness of the body of the material has less power to resist stress. Therefore, joints should be allowed at intervals where they will be as inconspicuous as possible, because as they are likely to occur anyway and are apt to be irregular in shape and position they are unsightly to the eye. If the surface is troweled smooth they are likely to show in an objectionable way. Unless the surface of the various coats are kept wet there is usually trouble from cracking. Some plasterers say that where the under coat is made lean with mortar and with plenty of lime and hair there is great deal less likelihood of its cracking. Care must also be taken to have a sufficient lap in the lathing; to have

the lath well tied together and also to the furring so that there can be no settlement or sagging of the lath or the furring to which the lath is attached. The cracks can be filled with cement or by a pump spraying grout or run over with a tool which will fill them. They are somewhat sure to show on a smooth surface anyway.

(*h*) *Washes.*—Washes of cement or lime can be applied to plastered surfaces which will fill the fine cracks and give a uniform surface to the material. Washes are frequently applied to monolithic surfaces and material cast in molds and form a rather pleasing treatment when carefully and well done. If cement is applied with a brush it is not likely to give a pleasing result but is pretty sure to be streaked and irregular in color and this color is apt to be a muddy yellowish green, rather than the gray of cement. If the wash is made very thick and contains sand and is plastered onto the surface and left in this condition or else lightly troweled with a steel trowel or with wooden float the appearance will be much more uniform and of a natural cement color. This is the most usual treatment given to plain monolithic surfaces, like bridge abutments, foundations and mills in inconspicuous locations.

(*i*) *Paints.*—Paint, either oil paint or special cement paints containing no oil, can be used to good advantage in painting cement surfaces either monolithic or cast, and will give pleasing appearance. The color is simply as much in the control of the designer as paints used on wood.

(*j*) *Enamel.*—Enamel paints may be used on cement if there is no opportunity for water or frost to get behind the enamel, which would cause it to peel off. Enamels which are baked upon a surface cannot be used as the process of baking would dehydrate the cement and cause the mortar to crumble.

(*k*) *Durability.*—There are examples of plastered surfaces which have lasted for fifteen years and are still in a perfect condition. There are numerous examples of moisture getting behind a plastered surface where this is applied to some solid back, as brick, terra cotta, stone or concrete, freezing and causing the plastered coat to peel. For this reason, plastered coats are not generally considered as durable or as desirable as a surface treat-

ment which is monolithic with the body of the surface treated. If the surface is impermeable to moisture and there is no chance for moisture to get behind the surface from any source, the plastering should be durable. If it thoroughly keys to the face its contraction and expansion will be the same as the base and therefore will not peel, due to an unequal stress between the two materials.

IV. ORNAMENTAL TREATMENT. POSSIBILITIES AND LIMITATIONS OF SURFACE.

(*a*) *Cast Concrete.*—Concrete can be cast in molds of various kinds with a considerable degree of ornamentation. In order to fill the molds, an excess of mortar is used and the finish is largely that of the mortar, the stone being used in the concrete merely as a filling to reduce the cost. Where the stone is exposed to view it is only possible in ornamental work where the surfaces are fairly plain and large area.

(*b*) *Cast Mortar.*—Ornamental casting is largely confined to mortar. Much sharper detail can be obtained than with concrete, even as sharp corners as are usual with limestone. Where sharp corners are not required and the surface is cut, scrubbed or sand blasted as previously described, colored sands or stone grit can be used to produce pleasing color effects.

(*c*) *Plastered Mortar.*—Plastered surfaces can be put on rough backs with good results. This is possible only with a mortar of rather a fine aggregate and therefore cannot give as large a variety of surface textures or colors as the cast, and the ornamental effects are largely those of straight molded members, as in a cornice, which can be run by the plasterer in place. These, however, are cheaper in cost than the cast and for this reason are quite extensively used.

(*d*) *Kinds of Molds.*—For rigid molds, wood is chiefly used and ornaments can be cast in any form in which the wood can be molded, except that no undercut work can be done as to remove the wood would break the mortar. When wood is used it must be carefully filled with paint or oil so as to prevent the absorption of moisture from the mortar which would carry with

it some of the cement bonding the mortar to the wood and thus destroy the face of the casting when the mold was removed.

Iron molds are used to some extent but are too expensive unless a great many castings are to be made exactly alike, in which case they are economical. It is not economical to make elaborate ornaments with iron molds on account of the expense of the mold. Sometimes stamped sheet metal can be used as a model for the face of the casting but the appearance is not pleasing and is seldom desirable.

Plaster of Paris is very extensively used and by cutting it into small pieces and putting together can be used for slightly under-cut work. Plaster of Paris molds can be used for quite elaborate castings and for castings containing as much as two or three cubic yards of concrete. As the plaster is not very strong in itself it is reinforced by burlap or some other fibrous material to give it strength. Its surface must be carefully treated to make it non-absorbent to moisture, as otherwise it will be damaged by the material cast in it. Each time a casting is made the surface must be again prepared to resist the attack of moisture. These molds are rather expensive on account of the high class of labor necessary to make them. It is usually necessary to make a model before the mold can be made.

Where a considerable amount of undercut work is required molds are made of glue. This requires considerable care and skill. The best quality of gelatine glue is required, mixed with the minimum amount of water necessary to dissolve and melt it at a low temperature. Around the model is placed a plaster form to receive the glue, which is poured in about 1½ in. thick between the model and the form. The glue is then cut in sections so that it can be removed from the finished casting, is removed from the model and re-assembled. It must be used before it has had time to dry up. Its surface should be coated with lard oil to prevent the absorption of water, which would disintegrate its surface. The lime of the cement also attacks the glue and decomposes it. For these two reasons castings of glue must be made with a minimum amount of moisture. Not more than three castings can be made before the glue will have to be re-melted and re-cast, and after three or at the most four castings it will be so impaired

in quality that it must be thrown away and new glue used. However, such undercut work can be done with glue molds that it is frequently necessary to use them.

Sand, either plain or treated with some material such as clay, loam, paraffine or acid, is used for molding purposes. The sand must be fine, so as to hold its shape, like sand used in iron foundries, and can be used for any object from which the pattern can be drawn. In fact, as elaborate objects can be cast in sand as in metal. As the sand can be used over and over again, the expense of its use is determined by elaborateness of the object which determines the amount of labor necessary to make the mold. A very promising departure in concrete molding is the use of sand and paraffine as a molding material. At 150° or above a little paraffine will disseminate itself through a great deal of sand. This sand shows the presence of paraffine very little and can be molded at 110° or thereabouts, *i. e.*, while slightly warm to the touch. Below 90° this material becomes quite rigid, and would seem for concrete casting to be ideal. Molds made of Portland cement and mortar have been used with success on plain work. It is the experience of one company having had years of practice in all kinds of cast work that absorbent molds into which is cast semi-liquid concrete give the most uniform color and texture and produce concrete of 10 per cent. to 25 per cent. greater density than when tamped, pressed or poured into non-absorbent molds.

V. WATERPROOFING.

(*a*) *Necessity.*—With thoroughly well mixed and carefully placed concrete made from materials properly graded for size so as to obtain maximum density with mixtures not exceeding 1-2-4, the resulting concrete would be so impermeable that waterproofing is unnecessary. With leaner mixtures or less care in the grading of materials the concrete will be somewhat porous, rendering necessary in many cases the waterproofing of the surface or in order to pervent penetration of moisture, by water-proofing the mass when it is cast.

(*b*) *Mixed in Concrete.*—There are many substances proposed for mixing in the mass of the concrete to render it waterproof.

Some of these are trade marked or patented. The Committee has made a study of and is familiar with many of these, yet does not feel justified in making a definite statement of fact regarding any of the protected trade substances at this time.

The fundamental principle in the waterproofing of concrete by addition of foreign substances is to introduce some material which is very much finer than the particles of cement that will mechanically fill the voids between the grains of sand and particles of cement, thereby rendering the whole mass denser. One of the most common materials used for this purpose with considerable success is lime. It can be thoroughly slaked and mixed with concrete as a putty, or better, thinned to a whitewash. Another form producing similar results is hydrated lime, which is a common lime slaked, dried and pulverized to a fine powder, and mixed dry into the mortar.

(*c*) *Method of Incorporation.*—With lime an amount of five per cent. by weight to that of the cement will give good results without the impairment of strength in the resulting concrete. If mixed dry it should be carefully sprinkled over the sand and cement and so thoroughly mixed by hand or machine as to obtain a uniform distribution throughout the mass. If mixed wet the putty should be so thinned that it can be as easily and uniformly distributed through the whole mass as is the water.

(*d*) *Surface Treatment.*—There are a large number of trade articles for the surface treatment of concrete, especially of dry blocks, which are practically colorless. The Committee is not at this time prepared to make definite statements regarding them and desires most extended discussion and fullest information upon any and all substances. One treatment only can be mentioned at this point, namely the use of paraffine, which is a staple material of mineral origin. This can be applied to the surface hot with a brush, or what is still better, the surface can first be heated so as to permit the hot paraffine which is later applied to soak to greater distance into the surface pores before it has time to cool and harden. This material, if used to excess, will give a glossy, oily appearance to the surface. Care should be used to avoid excessive use for this reason.

(*e*) *Surface Treatment Changing Color.*—This title implies

the application to a surface where color is of no consequence, as for instance foundation walls or the like. Here two general types of treatment can be used, those with a membrane substance like felt and those without. The most common substance used is some of the products of asphalt or tar. Their application is more a matter of engineering than surface treatment.

(*i*) *Mortar.*—For many places where a surface must be waterproofed a rich mortar carefully applied by skilled workmen will not only answer the purpose of finished appearance but will resist a water pressure of a number of feet head. It is a treatment which should only be used for good results by experienced and skillful workmen under intelligent supervision.

VI. LIMITATIONS, DEFECTS, BLEMISHES OF VARIOUS SORTS, AND REMEDIES.

(*a*) *Range of Colors.*—The range of color in mortar by use of pigments is limited to reds, yellows, blue and black. No other satisfactory color has come within the observation of the Committee. Red and yellow can only be used as faint tints, as to use them in quantities exceeding five per cent. by weight impairs seriously the strength. Blue shades are obtained by small use of lampblack, and black by larger use. The range of color in the aggregate is limited to the colors found in natural stone or other substances as previously mentioned, which is exposed later by the removal of all cement from the surface of these particles of aggregate.

(*b*) *Variation of Color.*—With the admixture of pigments, unless extremely thorough mixing is used there will be a variation in the color of the mortar. The great difficulty, however, is the variation in color between the different batches, due to a slight error in proportioning, the variation in the quality of the pigment, or the treatment during setting and hardening. Cement setting in a hot dry place will have a lighter shade than those setting slowly in a wet damp place even if all other conditions of manufacture are identical. Where the color is obtained from the aggregate, variation is due to a variable distribution through the mass or in placing an excess of stone in one part of the mass over that in another.

(*c*) *Craze Cracks, Checking.*—This has been one of the most neglected subjects with which the manufacturers and users of cement has had to deal. There is little question that checking is caused by deferential expansion and contraction, but years of continued and vigilant investigation has not furnished data from which definite conclusion as to the real cause of crazing in cement concrete can be obtained. The theory that cement when cured in air contracts and when cured in water expands, advanced by many, does not satisfy all the phenomena which have been observed in experiments. It is quite easy to prove that any concrete, irrespective of cement and aggregate, is never entirely free from crazing. It is well known that the greater the amount of cement the more crazing is obtained, also that careful curing greatly reduces it. With a view to bringing out discussion of this all important subject the Committee takes the liberty of appending some of the phenomena observed in experiments, and conclusion reached as follows:

1. That all Portland cement crazes. The denser the concrete the more marked are the craze lines, for the reason that it is the dirt which accumulates in same that makes them so apparent, and as the body of an absorbent concrete absorbs more of this dirt than a dense concrete, but uniformly over its surface. It is only the fact that the dirt collects in the craze cracks that makes them apparent on the denser material.

2. That there is quite often an exudation from cement concrete which collects in craze cracks, which when analyzed is found to contain practically all the constituents of which Portland cement is composed, showing that more or less of this material is absorbent and carried to the surface by the moisture when the concrete dries.

3. Exposure of green concrete to draughts, sun and rain, appreciably increases the amount of checking, but that no matter how carefully concrete is protected or for how long a period, it will eventually craze and check on exposure. This has been proved by curing concrete in water kept at very nearly a constant temperature for a period of two years, and that casts so made when sawed in half thoroughly dried out, and exposed to the air, checked inside of thirty days.

4. That such crazing or checking is not confined entirely to the surface of concrete.

5. That the addition of waterproofing compound does not stop checking, but by the preventing of concrete absorbing dust and dirt prevents it from showing temporarily.

6. That the more thorough the mix, and the more careful the proportioning of the aggregate so as to reduce the amount of cement necessary to make a dense concrete, materially decreases checking.

(*d*) *Expansion and Contraction Cracks.*—Such cracks are due almost entirely to thermal stresses and can be overcome and controlled by proper reinforcement with steel in lengths of concrete up to 500 feet and perhaps longer, but as such would be treated under the subject of concrete design.

(*e*) *Irregular Size.*—The prevention is stronger bracing of molds; the correction; chipping before or after the work is hard. This is a frequent point for criticism against appearance of concrete. It is not a blemish when the work is well done any more than the mortar joints in brick and stone work. It may be minimized by cutting back the surface of the work before it is hard and grouting on a new one.

(*f*) *Mortar and Stone at Horizontal Joint between Days' Work in Concrete Wall.*—In building monolithic walls where work is stopped for the day, an excess of mortar is frequently tamped to the surface and sets. The following day when soft concrete is added an excess of stone settles through the mortar to the hard surface below so that after cutting the surface a line is shown about a half inch wide of mortar with an excess of stone directly above. This is avoided by scraping off a half inch of the surface when the day's work is done before this has had time to set and by care in using a stiff mix in the first batch deposited next day so that the stone is held uniformly distributed in the mortar which is too stiff to permit the stone to settle through it.

(*g*) *Patches a Darker Color.*—These seem to be caused by using a richer mixture, steel rubbed off from trowel with which applied, less surface evaporation from patches, or bringing to surface by trowelling of the dark colored cement particles or the aggregates. It has been conclusively demonstrated that with due

care and by addition frequently of some material to lighten the color of material put into a patch, that the patch cannot be detected even after several years of exposure.

(*h*) *Efflorescence, Cause and Remedy.*—Efflorescence is caused almost exclusively by percolation of moisture through a wall. It is not to be observed where a wall is always dry. Portland cement always contains some free lime and this is brought to the surface in solution by water and left there by its evaporation. This efflorescence has been chemically analyzed and found to be almost pure carbonate of lime. The remedy is to avoid percolation of water through a wall. If this tendency is very slight, as for instance in the wall of a building which is somewhat porous, allowing a driving storm to soak into the surface in such quantities as to later percolate to the surface bringing with it in solution lime, the appearance of efflorescence can be very much reduced or practically removed by waterproofing the surface with some compound which will prevent all absorption and percolation whatsoever.

(*i*) *Porosity. Cause and Remedy.*—Porosity is a lack of density; that is not getting enough material into a given compass. The causes may be too little cement to fill the voids, too much fine sand, not enough fine sand (*i. e.*, sand not properly graded), stone not proper size or properly graded for the work, not enough water added to the mixture to lubricate it and feed the cement.

(*j*) *Frozen Surfaces.*—Freezing retards the setting of cement but does not destroy it. If the surface freezes the set is retarded so that the portion behind which is not frozen, setting faster, breaks the bond between the two, causing the frozen portion to scale. The remedy after the surface is frozen where the material lost has not got to be replaced, is to re-surface that material which is left. If it must be replaced the texture of the surface originally desired must determine largely the method of treatment. If this be a plastered surface it is a simple matter to roughen up the back to give a key for plaster and to place it on. If it is to be a tooled concrete surface, then a sufficient mass must be removed to enable a new facing to be placed, including aggregate of the same size and proportions as in the original work, in order to build out the face and also to have sufficient strength and

stability either to stand by itself or to be properly keyed by suitable methods like the use of reinforcement, to the back.

Dusting. These troubles are due to soft sand, unsuitable foreign material in sand, too little cement in mixture, bad mixing, too much time elapsing between mixing and finishing, finishing mixture too dry or too wet, use of "dryers" (*i. e.,* dry cement with or without sand to dry out the surface so that it can be quickly finished), permitting the surface to dry so rapidly as to impair the setting of the cement. When a thin surface is placed on one which has become hard there is liable to be dusting because there is no absorption from the concrete to take care of the excess moisture in the mortar. It has therefore got to come to the surface and in so doing it brings the soluble salts of Portland cement called laitance with it and some of the finest particles of the cement, the impalpable powder, to the surface, both of which are easily brushed off, and thirdly, because the moisture comes to the surface it cannot be troweled as soon as it ought to be, and when it is troweled so long a time has elapsed that the setting of the cement is broken up or impaired, thus materially reducing its strength. The remedy, where color is not an object, is the application of one or two coats of well boiled linseed oil. Paint is sometimes used, but is not a satisfactory material because as a rule it does not harden the dusty surface and the dust prevents its bonding to the mass below so that it scales off, leaving an unattractive appearance. In some cases the top may be ground off as in terrazzo work, until a hard surface is obtained.

VII. SPECIFICATIONS.

The following specification is suggested for furring and metal lathing to obtain results of (III-b):

Furring For Steel Frame Buildings.

The furring for steel frame buildings shall consist of ¾-in. channels, or 1 x 1 x ⅛ in. angles extending in a vertical direction and spaced 16 in. center to center. Horizontal steel girts shall be provided (as part of the structural steel) spaced not over 8 ft. apart, consisting of such shapes that the furring can readily be attached and supported. If the girts are spaced more than 8 ft. apart, the furring shall be proportionately increased in strength.

Furring on Wood Frame.

The furring over boarding of wood frame shall consist of ¼ in. round or square rods extending in a vertical direction and spaced 16 in. center to center and securely stapled in position. (This furring serves two purposes, viz:—to support the lath free from the wood, and second, to form a reinforcement for the stucco wall.) In this construction weather boards may be omitted, but this is not desirable. If weather boards are used, building paper should be placed first before furring is applied.

Metal Lath.

The metal lath shall be of sufficient rigidity to readily take mortar when supported by furring spaced 16 ins. center to center. For exterior walls, it shall be protected from rusting by being entirely galvanized or treated by any other equally efficient process.

The lath shall be wired to the furring angles or channels every 8 ins. with No. 18 annealed galvanized steel wire or stapled to the wood support every 8 ins. (in the length of the furring rods) with staples which are galvanized or otherwise equally protected from rusting.

The following specification, prepared by the State Architect's office of the State of New York, and Green & Wicks, architects, Buffalo, N. Y., is used for ornamental work by the State of New York and covers work given under Division IV fairly well:

Specifications For Cast Cement Stone.

All cast stone shall be made of high grade Portland cement, such as will pass the standard specifications* of the American Society for Testing Materials, and of a brand satisfactory to the architects, and an aggregate of uniform color and texture and free from iron and other foreign material liable to discoloration. Preference will be given to aggregates of marble or granite.

The cement and aggregates shall be thoroughly mixed in a proportion of one part of cement to not over six, nor less than four parts of aggregate, all measured by weight. The aggregate shall be made by crushing selected pieces of stone to insure uniformity of color and texture, and shall be screened into at least three sizes the largest of which shall not exceed that which passes a ring of one and one-quarter inch in diameter, and the various sizes shall be proportioned for maximum density. There shall be at least fifty per cent. of such a size of aggregate that will pass one-quarter inch ring and will not pass a one-sixteenth inch ring.

The concrete for making the cast stone shall be mixed with not less than fifteen per cent. of water by weight and shall be mixed by a machine, preferably of the rotary type. If cast in a semi-liquid condition, it shall be continuously agitated up to the time it is deposited in the mold.

* See Standard No. 1 National Association of Cement Users.—ED.

All casts shall be properly seasoned by being kept moist and away from the sun's rays and draughts for at least ten days after being made.

After having been seasoned for at least ten days, all exposed plain surfaces of the stone shall be tooled with a drove finish of four or six cuts to the inch as the architects shall specify. This tooling shall preferably be done by grinding the grooves by the use of an abrasive material so that the larger aggregates will not be disturbed or in any way shattered.

All cast stone shall be of such quality that it will pass a test at the age of twenty-eight days of at least 1,200 pounds compression per square inch and shall not have an absorption to exceed five per cent. when thoroughly dried and immersed in water for forty-eight hours. All lintels, bearing stones and others subjected to cross bending shall be reinforced by means of steel rods placed about one inch from their tension surface, and the total sectional area of the steel shall be equal to one-half of one per cent. of the area of the concrete in the member reinforced. When any casts exceed in any dimension, twelve times its least dimension, it shall be reinforced to insure safety in handling.

Samples of cast stone on which bids are based shall be submitted for approval. Preference shall be given to stone cast in any established factory. All casts shall be provided with steel bonds for the purpose of tieing into the backing and with hooks for handling and lifting which shall be placed in the stone while casting.

Cast stone need not be plastered or painted on the back as specified for Indiana linestone.

VIII. COSTS.

The cost of unskilled labor for picking or rubbing concrete when six to twenty-four hours old is about one cent a square foot. If two days old, so that fiber brushes and water have to be used the cost runs from two to three cents for actual dressing of the surface. In order to be able to remove the forms to get at the surface at these ages it will have to be designed in such a way that its price may vary from nothing to five cents a square foot.

For a special facing material of an inch thick of one cement, one and one-half sand and two and one-half of fine crushed stone or pebbles, placed at the same time with a coarse backing in the walls, will add about three and one-half cents per square foot to the cost of the surface. This cost is independent of the method of treating the surface later.

Tooling by multiple picks by common labor when the surface

is green will cost from three to four cents per square foot; when hard, from five to ten cents.

The cost of the use of pneumatic tools varies materially with the size of the job and to what extent the work is scattered. For long low walls pneumatic tools will cost more than hand. For large areas like the soffit of a big arch pneumatic tools will be cheaper than hand work by one-half to one-third.

Sand blasting when the cement is one to two weeks old will cost about the same as bush hammering; when older it will cost considerably more.

Extended experience gives the following cost data: For hand tooled cast concrete four or six grooves to the inch with steel tools, the cost on a contract of tooling some 10,000 sq. ft., with skilled labor, was fifteen cents per sq. ft.; the same kind of tooling with pneumatic tools about twelve cents; the same tooling done in a factory by grinding with a special designed machine, one cent. This special designed machine consists of cutting wheels suspended on an arm like a pendulum wood-working saw revolved at a high rate of speed, so that concrete of almost any age could be cut without disturbing the stone in the aggregate. The cost of crandalling, being an average of many jobs, with skilled labor, is about ten cents; with unskilled, about five cents.

TOPICAL DISCUSSION ON THE EXTERIOR TREATMENT OF CONCRETE SURFACES.

The President.

THE PRESIDENT.—There is a great deal of work in which concrete is treated naturally, but one of the principal difficulties seems to be the effect of crazing and hair checking. It might be well to discuss some features connected with the handling of concrete or mortars so as to secure pleasing effects devoid of hair checks, crazing and unsightly marks which tend to detract from the character of the work. There evidently is a knack in the art of using concrete which we have not been able to fully understand, and we can probably obtain very many pleasing effects in this country, but thus far, our mortar surfaces generally show hair checks which render the structure unsightly. Such unsightly work is not seen abroad, and I think the reason is that the workmen know how to handle the materials. Those of us who have followed the development of the cement industry in this country have come to realize the fact that at first, the utilization of cement was a very crude process, consisting solely of mixing the material with water and getting it into a condition so it would harden. The conditions which affect this hardening have not yet been worked out.

Lime is one of the most ancient materials we have in masonry, and in looking over different parts of the world it is found, that while lime is a very poor material, those who have studied its qualities and know how to use it, can get remarkable results. In Mexico, for example, they can beat lime mortar, so that it becomes so hard as to shed water. They produce a wearing surface, as hard as the ordinary cement. Now it is quite evident that they have learned to appreciate the possibilities of that material.

In using cement mortar I think there is a great tendency to work the material too much, as this brings fine particles and the more soluble compounds to the surface, producing checks and crazing. There is also a tendency to use too rich a mixture which also has a similar effect.

The President. I was impressed with the work that is being done abroad. The mortar used was for the most part rather dry, and there was not a tendency to keep working and pounding it. It is not so much the working of the mixture together and the mixing of it that does this damage, but it is the pounding of the material after it is in place, which tends to work the coarser particles away from and bring the finer particles to the surface. Various methods have been resorted to here to avoid these cracks by treating the concrete to so distribute the hair cracks as to make them invisible to the eye, or break up their continuity, by exposing the aggregates, scrubbing the surface or pebble dashing. The cracks pass around the particles and their continuity is so broken as not to be evident to the eye. The cracks are there just the same and whenever you take a smooth plaster finished surface, the shrinkage and contraction cracks and crazing that occur render it unsightly.

The plastered house in Europe is a common thing, and it is not unsightly. You do not see the checking and cracking except in some cases of bad workmanship. The great percentage of those houses after years of exposure look well, and I believe it is wholly due to the manipulation of the material that such results are obtained.

Our sectional Committee on the Treatment of Concrete Surfaces is trying to prepare a Standard as to how work should be executed, and I think probably this will serve two purposes: first, it will enable the men who are engaged in this work to indicate in a practical way how it should be done; and the second, it will enable the architect who wants to obtain certain effects in the surface finish of concrete to insert such a standard bodily in the specifications, so that those who are working in that particular line, know just what is wanted. I think work along this line will be very helpful in obtaining pleasing results in the use of cement.

Mr. Mensch. Mr. L. J. Mensch.—I beg to differ slightly with the Chair in that there are no fine checks in European plaster work. I am familiar with cement plastered houses and used to disfigure them by drawing pencil lines along the cracks. The fact is, they mix the cement with a good deal of lime and hydrated lime and

get unsightly cracks even then. I do not think anybody in Europe would undertake to plaster a building and guarantee that there will be no checks. There are cracks and if you look close you will find them. Of course a man who does not look very closely will not see them. Mr. Mensch.

THE PRESIDENT.—The Chair wants to correct a false impression. He did not mean to convey the fact that there would be no cracks, but that in looking at a plastered surface the unsightly cracks which are quite evident in most work here, are not so evident there. I refer particularly to work that has been done at Berlin and Vienna, which was on plastered houses. In two or three cases I had plastered buildings under particular observation, examining the surface of the buildings very closely. The buildings had been plastered certainly for more than six or seven years and did not show cracks on the surface that were so unsightly as to be objectionable. The President.

MR. MENSCH.—There is another reason in that they make the first story either of natural stone or artificial stone slabs. It is easier to prevent cracks in a factory made slab than in a plastered wall. Mr. Mensch.

I would call attention to the fact that even the government buildings are of cement plaster. The University of Vienna is cement plaster above the first story, and it is a $5,000,000 build ing, which is a great deal more there than here.

THE PRESIDENT.—The surfaces referred to were regular smooth mortar surfaces, such as one would ordinarily expect to see checks in. The President.

I think as a rule the plaster house in Europe is in greater favor than here; in fact, the plastered house is the rule. I think even new houses being erected usually have brick walls, which are laid up with wide joints for the purpose of getting a surface on which to plaster. One of the advantages of the application of plaster is that the coat is not too thick, and they try to get a smooth surface with as thin a coat of plaster as possible.

MR. C. F. KLEIDERER.—I would like to ask as to the percentage of hydrated lime it is best to use with plaster, and the best way to incorporate it in that mixture. I have seen lime set in 1- minutes. Mr. Kleiderer.

Mr. Mensch.

Mr. Mensch.—Mix the materials dry. They do not use so much hydrated lime abroad, but ordinary quicklime which is a year old, kept in covered pits.

The President.

The President.—The Romans, when they first began to use lime mortar, put it in pits and let it stay there for several years before using it. Of course, there are various methods by which lime is reduced to an impalpable powder and hydrated. This is much better than where the lumps are allowed to break down in their natural way. In the use of lime for that purpose it is absolutely necessary that it shall be fully hydrated.

Mr. Kleiderer.

Mr. Kleiderer.—The trouble I found was in getting hydrated lime thoroughly mixed with sand and cement. It takes lots of mixing to do it.

Mr. Phillips.

Mr. W. B. Phillips.—Hydrated lime when used for waterproofing concrete, stucco, etc., should be mixed thoroughly dry with the cement before adding sand and water. The hydrate should be mixed dry first with the cement, because most of the sand obtainable for concrete work is damp, and an even mixture cannot be obtained using hydrated lime and moist sand.

I have found by test that it is not advisable to use more than 15 per cent. hydrated lime to the weight of cement. When used in this proportion it is equal if not superior to any of the patented waterproofing compounds, besides being much cheaper. The University of Wisconsin and others have made some very interesting tests with hydrate as a waterproofing material which further show that using the proportions mentioned it materially increases the strength of the concrete.

Mr. Chapman.

Mr. Cloyd M. Chapman.—Mr. Kleiderer referred to the difficulty of mixing hydrated lime with sand and cement. I believe that it is as difficult to mix sand and cement. When sand is mixed with cement their colors do not differ enough to require very thorough mixing to produce an apparently uniform color. If one endeavored to mix a white cement with a black sand, I believe it would be as difficult to bring the mixture to a uniform color as it is to bring a mixture of white lime and grey cement and sand to a uniform color. The difficulty referred to simply illustrates the necessity of much mixing to secure uniformity, no matter what the constituents of the mixture may be.

THE PRESIDENT.—I think the best way to test it, after mixing, is to break it open, and you generally find little white spots, which show how thoroughly you have mixed. **The President.**

MR. MENSCH.—It is really very hard to mix two materials thoroughly, and in order to mix cement with any color to obtain a uniform appearance, it must be done in a mold and mixed for at least an hour to get good results. An absolutely uniform mixture cannot be obtained by hand mixing. **Mr. Mensch.**

THE PRESIDENT.—It is a fact that those who are skilled in plastering can get practically the same results without the use of lime. It is the man unskilled in the application of plaster that has to resort to hydrated lime in order to secure the desired conditions. I have observed Italian laborers putting on plaster, obtaining smooth finishes, even placing plaster on hardened monolithic concrete piers, without the use of lime. They obtained very smooth mortar finishes which have crazed very slightly after many years. It is in the manipulation of the material largely that the results are obtained. **The President.**

I do not believe in the use of hydrated lime in connection with cement. I think it should be omitted where it can be avoided, even if the cost is increased. It might be said that waterproofing must be used in a concrete block because you cannot get it dense without. Now manifestly there is no man who would not be glad to omit waterproofing if he could.

MR. MENSCH.—It certainly costs more money to work without hydrated lime or with lime mixed with cement. **Mr. Mensch.**

A block maker is sure to use waterproofing in making a concrete block dense rather than by hard tamping, and it is found to take the test.

MR. CHAPMAN.—I would like to ask whether cement which will not stand the boiling test due to lack of aging, will contract more than properly aged cement, and whether unsoundness affects the coefficient of contraction to any great extent. The cement manufacturers in their bulletins or pamphlets recommend the use of high percentages of hydrated lime up to equal parts by volume. As they are the last people who would be expected to recommend anything that tends to reduce the quantity of cement used, it would seem they would have to be thoroughly **Mr. Chapman.**

Mr. Chapman. convinced that certain quantities of lime improve the result before they would recommend the substitution of lime for cement. Personally I agree that about 15 per cent. is as much as should be used in concrete—about 1/6 by weight or 1/3 by volume. I think that is the limit except for plaster and mortar, but the cement manufacturers, who are interested in the sale of cement, recommend more.

Mr. Watson. MR. CHARLES D. WATSON.—I cannot see how the addition of hydrated lime to a Portland cement concrete, whose surface is to be treated, can be of any advantage, unless the concrete is of such poor quality that the lime is required to give greater density.

The first consideration in making a concrete, the surface of which is to be finished by any of the common methods, is to produce a concrete of the highest grade possible, as regards texture and density. This can best be done by the proper selection and proportioning of aggregates.

The subject of crazing and hair checking is one on which I naturally hesitate to express my views, as there is such a variance in opinion among experts as to its cause and remedy. In my opinion it is one of the most neglected defects in Portland cement concrete, and its cure has not received the attention it warrants. There have been many reasons and remedies presented by various authorities, but I am convinced by the results of several years' observation of the phenomena of crazing that no one has yet given us a complete solution, or a satisfactory explanation of what actually causes it. In my ten years' of experience in the manufacture of concrete products I have yet to see concrete made in any form or proportion that, by proper treatment and exposure, would not develop craze marks to a more or less degree.

The amount of crazing visible on concrete depends a great deal upon its quality. The more dense the concrete the more apparent the craze marks, for the reason that craze marks would not show at all but for the fact that they collect dirt. The ordinary hollow building blocks are usually made so porous that all surfaces collect the dirt uniformly, which makes it almost impossible to see these craze marks. Some authorities insist that these craze marks appear on the surface of concrete only, and that when the surface is removed, after the concrete is seasoned, by

cutting or acid treatment, it eliminates crazing. The writer's experience convinces him that this is not the case. The removal of the surface eliminates the dense rich cement coating on all concrete which has and shows more crazing than a surface where there is less cement. Also in the latter case the cracks follow the edges of the aggregate and become invisible. **Mr. Watson.**

I have also proven to my satisfaction that no method of seasoning will entirely overcome it. In the experiments which I have carried out I have had samples of concrete made by various methods from various materials and proportions of both aggregates and cement, and various methods of seasoning have made little difference in the result. In fact I have made samples that have been left immersed in water for two years and when removed, sawed in two and exposed to the air have shown craze marks on the interior surface in 30 days.

The cause of crazing I think we will all agree is due to expansion and contraction. We know that when concrete sets in water it expands, and when it sets in air it contracts, but I have never yet succeeded in finding an authority that has satisfactorily explained why cement acts in this manner. It is a subject that I would like to see given more consideration by the chemical experts and this Association.

MR. CHAPMAN.—Magnesia is an objectionable constituent of cement beyond certain percentages. Is it objectionable to use screenings from crushed magnesia limestone in the making of a cement mortar and is the magnesia in the stone detrimental to the cement with which it is mixed? Is there any objection to the use of a hydrated lime containing high percentages of magnesia? **Mr. Chapman.**

MR. MENSCH.—I think it is. I think the use of screenings from crushed limestone containing magnesia is injurious and certainly makes the setting of the mortar much slower. **Mr. Mensch.**

MR. DANA G. CHANDLER.—I have had a little experience with crazing and discovered sometimes that I have troweled a little too much. It seemed as though I had driven the cement to the surface, it was worked too much. I have not had very much trouble. **Mr. Chandler.**

MR. EMILE G. PERROT.—While I am not a practical cement worker, I have observed a great deal of work and find that cement **Mr. Perrot.**

Mr. Perrot. pavements and work of that kind if granular, shows fewer hair cracks. Take a terrazzo floor, for instance which is nothing more nor less than a cement floor with stone thrown on the top and then beaten down and polished, there is a big proportion of aggregates and very little cement, consequently there is very little shrinkage and crazing. Now observation on terrazzo floors shows me that the leaner the mixture for terrazzo floors the better the result. In the Congressional Library in Washington is one of the worst pieces of terrazzo floor in the United States; here the engineers required a very rich mixture for the cement mortar for these floors, and they are cracked all over. Now cracking is nothing more nor less than enlarged crazing due to a big bulk shrinkage.

One of the cheapest pieces of terrazzo floor work in Philadelphia, where they could not get it cheap enough, is almost perfect, due, as far as I can see, to not using too much cement in the surface, and consequently having less shrinkage, and less chance for the cracks to appear. The old Stewart pavements in Philadelphia, have been around the city hall for 30 years, and they are worn to the stone, in fact, they are made similar to the terrazzo floor, only they are not polished. Now the Stewart pavement, to my mind, is the ideal way of making a cement pavement. You have a large amount of aggregates which come to the surface, and only a little cement to hold it together, the same as this terrazzo floor. I think the economical cement pavement is the one with so little mortar that the stone practically constitutes the wearing surface.

The President. The President.—The Chair would call attention to the fact that the checking of these pavements occurs, but walking over them fills the cracks so they are not noticeable. A sidewalk, for instance, which in dry weather does not appear to have checks, immediately after a rain shows hair cracks all over the surface. Of course in vertical surfaces or surfaces above the ground the tendency to develop hair cracks is more noticeable. I agree with Mr. Perrot that it is certainly a matter of shrinkage and there is no doubt that different cements, differently aged cements, cements of different composition, have different rates of shrinkage. This has a very important bearing on the question of cracks and

crazing. It is also true that the richer the mortar or concrete the more it will craze. The problem is to know just how to work a lean mixture to avoid cracks, and generally they resort to lime mortar, hydrated lime, in order to make the mixture sufficiently plastic to be applied by the workmen. **The President.**

Mr. Maynard.—It will be noticed in terrazzo floors that cement is retarded from setting too quickly by rolling, and is kept wet while it is being rubbed and polished by hand or by machine. **Mr. Maynard.**

Mr. W. M. Newton.—The subject of crazing is a very serious one to me. We make a sprinkled cured block in which we use one part cement to three parts fine aggregate and add to this whatever coarse aggregate the work will allow. **Mr. Newton.**

I subject the blocks as soon as they are molded to a spray so fine that it might be termed a vapor. This spray carries the cement on the surface of the block in suspension back into the block, thereby exposing the aggregate and producing a very pleasing surface. By supplying the moisture to secure the full initial set of the cement, a very good quality of block is obtained aside from the fact that we have some trouble with crazing after curing.

I do not think that limestone has the effect on crazing as has been stated. The limestone screenings we use have such a large percentage of flour that we never use it for facing, but occasionally use it as a part of the fine aggregate in the back of the block. The crazing all occurs in the facing of the block where only clean selected and well graded aggregates are used.

The President.—The Chair would call attention to the fact that there are two other sources of difficulty in surface finishes. One is the use of excessively fine sand, and another is the drying out of the concrete surface. Rapidly drying out of the surface of the concrete is bound to produce checking and cracking. But in cases where the surface is kept wet or kept away from the currents of air the tendency to craze is not so great. **The President.**

Mr. Maynard.—Our concrete plant is located in a basement, and we are careful about the conditions. We have plenty of water and keep the blocks drenched. I have had work which I was exceedingly anxious to turn out particularly well, **Mr. Maynard.**

Mr. Maynard. that has cracked after being kept thoroughly soaked for fourteen days.

We have frequently used a great deal of fine material in the body, but in the facing of the blocks where the trouble was with crazing, we used a selected material that would not run over 3 or 4 per cent. through a 100-mesh screen. It was either sand from the Delaware Bay or a high quality crushed granite. We have been very particular about our facing, and do not use a fine facing. In fact, it is so coarse that it is hard to pack it close enough together to present an even smooth finish.

The cracks develop very fine and keep on increasing in size and number. They are very fine to start with. They will develop six months after the material, apparently perfect, is put in the yard, and you cannot detect any sign of crazing until four, five or six months afterwards.

The percentage of sand is 1 of cement to 3 of sand, and in the body of the blocks we use as large a stone as we can ram together compactly. We usually use a 1:3:4 mixture for the body.

Mr. Russell. Mr. R. H. Russell.—I have had some trouble, but found it came from the difference in the proportions, that is too coarse an aggregate in the body of the block. I think it would be well to use a little more sand in the coarse mixture. My theory is that if the voids are not all filled in the coarse aggregate, the shrinkage is not nearly as much as of the richer facing.

Mr. Wason. Mr. Leonard C. Wason.—There is one form of crazing I have never been able to explain or obtain a satisfactory reason for. In a combined gutter and curb, laid at the same time of the same materials in every way, the facing backed up against wood, but the vertical face taken down in time to finish wet with the gutter, the gutters remain perfect for years while the vertical face of the curb cracks or crazes. Because the conditions were so identical in this treatment I am of the opinion that vertical faces are more apt to crack than horizontal faces. Why, I do not know; there seems to be no special reason for this action. It occurs so generally that it must be due to a physical property of the material.

THE PRESIDENT.—I think it is because horizontal crazing is evident and vertical is not. People walking over that surface would tend to cover those little checks, whereas in the vertical face they have a chance to go on in an uninterrupted way. **The President.**

I think the working of the concrete surface which moves the little coarser particles away from the face and brings up a continuous skin of cement, is the reason for these hair cracks becoming noticeable. Now any process which tends to remove that skin by scraping or tooling does not necessarily stop those cracks from being there, but produces a rough surface around which they can occur without being noticed, and unless the amount of shrinkage be very great they are not likely to develop into cracks that would be noticeable.

MR. PHILLIPS.—Some one asked if all cements required aging. Cements made in some localities require aging, while others do not. That is, some cements have a large percentage of free calcium oxide which should be allowed to air slack before it is used, while others have no free lime, and require no aging. I have noticed no difference whether the cement was made of rock or marl. **Mr. Phillips.**

MR. JOSEPH A. BLACK.—In the matter of concrete surfaces, building blocks and construction work in which hydrated lime is sometimes used, I would like to know whether hydrated lime containing 45 per cent. magnesia to 55 per cent. calcium, or one containing 97 or 98 per cent. lime calcium is the best for such work. Manufacturers of high calcium hydrate claim that only lime analyzing 97 or 98 per cent. lime calcium can safely be used in concrete work, i. e. surface work, blocks, etc. Others contend that hydrate analyzing as high as 45 per cent. magnesia makes a better mortar. I am not taking the part of any lime firm in this controversy, but I would like to find out which is most beneficial when used in concrete work, and which, if either, should be avoided. **Mr. Black.**

MR. PHILLIPS.—It is more desirable to use a high magnesia lime than it is a limestone high in magnesia. It produces about the same results in the concrete. **Mr. Phillips.**

THE PRESIDENT.—The Chair would state in reference to the question of oxide of magnesium and oxide of calcium, that **The President.**

The President. is, high magnesium lime and high calcium lime, that it sometimes happens in the burning that the high temperatures may overburn the lime and in consequence the oxide of magnesia is slower in hydrating than the oxide of calcium. Unless this lime is thoroughly hydrated before use it is likely to hydrate after it is in place. The oxide of magnesia has the phenomena of swelling which, occurring after the hydration has taken place, is likely to disrupt or otherwise injure the surface or mass. This also applies to all forms of lime; if the lime contains magnesia and is not well burned the difficulty of thorough hydration is increased. I never saw any evidence that a limestone containing magnesium had a detrimental effect on cement mortars or concrete.

Mr. Phillips. MR. PHILLIPS.—The whole proposition sifts itself down to this: I firmly believe the reason why so many objections have been raised to the use of lime in cement mortar, is because many of the limes have an excess of magnesia, and it is very difficult to get pure, hydrated lime.

Mr. Russell. MR. RUSSELL.—I would like to ask what effect, if any, hydrated lime would have on the shrinkage of cement mortar.

The President. THE PRESIDENT.—I think it is a fact that the lime and other soluble matter produce shrinkage. It is the contraction in the volume of the material; any material in which an excessive quantity of water is used has a tendency to shrink when this water is driven off. The water occupies space, and when it evaporates leaves voids; upon evaporation, especially rapid evaporation of that water, there will be a tendency of the solid particles to come together, and the very process of coming together produces cracks. As an illustration of this point I direct attention to a pond containing a large amount of fine clay. After the water has evaporated, as during a dry season, cracks may be seen all over the surface. The reason is that this fine clay or sediment, which was in an extremely fine divided state and silty in its character, contained an excessive amount of water, and when that water evaporated the solid particles came together and produced cracks. The same phenomenon occurs in a cement surface.

Mr. Werking. MR. FRANK D. WERKING.—I think in many cases cracking in concrete buildings is caused through putting the blocks on a

green base. When a base is used say 3 ft. wide and 2 ft. thick, how long should it be before a block wall can safely be placed on it? **Mr. Werking.**

The President.—The placing of blocks in a wall depends, of course, entirely on the strength and size of the blocks. The conditions would be the same in a stone wall. If you used large pieces of a very soft stone with low strength and the foundation was not sufficiently rigid to prevent settling, the unequal settling of the wall would produce cracks, and I think this is true with a great many blocks. The blocks are laid up with mortar joints and perhaps the shrinkage of those joints will produce irregularity in the loads that are on the wall, and the result is the block will crack. The proper method for using blocks depends on so many conditions that the Chair certainly would not want to lay down a specific rule. The amount of materials, the proportions of the block, the thickness of the webs, the age of the block and the time of the year in which it was cured, whether it was cured by steam or natural conditions, all have an important bearing on the hardening of that block. **The President.**

The greater the strength of the block the less the danger from unequal loading of the wall. Small blocks show less cracking because probably the joints take up the unequal loads. Brick walls, as a rule, show few cracks, because there are so many joints to offset these cracks that they pass around and not through the bricks. The larger the block, the less its strength, the greater is the danger that unequal settling will produce cracks through the block. Mortar, with coarse particles and uneven joints result in unequal settlement and produces cracks.

Mr. Werking.—It would not be advisable to put on a heavy wall until the foundation was firm, no matter how long it took. I think in order to avoid trouble it is necessary to have a firm foundation before attempting to put a block on top of it. **Mr. Werking.**

Mr. Kleiderer.—I would like to ask about the use of cement as a pavement and also as to cement mixed with oil to be used as a coating on wood. **Mr. Kleiderer.**

The President.—In the use of cement as a paint on iron, *i. e.,* cement mixed with water, if the iron is not coated with grease and otherwise clean, the porosity of the surface of the **The President.**

The President. iron is sufficient to allow of a thin coating, that is, the material will go into the pores and produce a coating which will stay. I do not mean a coating an inch or more thick, but simply a covering of cement and water as will coat and give it a cement color. However, the iron must be free from grease, rust and scale, otherwise you cannot get good contact.

Mr. McCullough. MR. MCCULLOUGH.—I had a contract a number of years ago in which the specifications required the reinforcement to be free from all rust and the engineer in charge wanted it painted with a cement wash when received from the cars and stacked up waiting to be used. We were unable to make water mixed with neat cement stick to the iron as it would flake off after a while. A German engineer who was working as my assistant—eleven years ago—suggested the use of skimmed milk, stating it was used abroad. We used skimmed milk instead of water with success and used the cement neat. The milk seemed to hold it in suspension better than water. The caseus part of milk seems to act as a very good carrying medium. I used this in a number of cases for the protection of iron work, and know of a great many cases where skimmed milk as a carrying medium for cement wash, taking a neat cement wash, is used as a waterproofing paint. A number of contractors out in Iowa and other sections are using it freely for plastered cement roofs. Over the shingle roof they lay metal lath with a small web and plaster it. Over this they put one or two paint coats of skimmed milk and cement, and it seems to make a very good waterproofing paint lasting two or three years. Skimmed milk mixed thoroughly with the cement will give a better paint for iron surfaces than cement mixed with water.

I have tried unskimmed milk and did not obtain nearly as satisfactory results; it curdled badly. We found that if any water was added there seemed to be a tendency for the liquid to part with the cement, that was otherwise held well in solution, and there was quite a deposit in the bottom, not noticeable to any extent when milk alone was used. Less stirring was required to keep the cement suspended in the milk than when water was added. An analysis of the mixture shows it very similar to that of ordinary cold water paint.

Mr. Perrot.—I think it would be well to bear in mind that concrete in comparison with other building materials is not the only one that crazes. Almost every building that is put up with that ornamental terra cotta trimming crazes. So much so that in one building we put up the president of the corporation called my attention to the fact that the material was crazing before the building was up two stories, and asked me if I thought we had to pass that material. I told him yes because that was the only kind we could get. Concrete crazes, but usually that is noticeable because of the large surface, and in ornamental terra cotta the surface is not so large. I do not think we need worry so much about that feature if we can do something to break up the surface. **Mr. Perrot.**

REINFORCED CONCRETE FOR THE SMALL HOUSE.

By C. R. Knapp*.

The small and medium-priced house in reinforced concrete is to-day a reality and not only a theory. It was not so long ago that concrete was considered suitable for the large structures only and even to-day the concrete contractor will claim that a small concrete house cannot be built in competition with other building materials. They are right, in so far that it cannot be done using their methods, which are only adapted to the large structure. It can be, and is being built successfully, by using any one of a number of systems which are adapted for the small work and would be just as much out of place in large work as the large methods are in small work. The small house is the one thing nearest to the masses. Anything that pertains to a home appeals to them. They are watching all concrete work with much more than ordinary interest. A knowledge so gained speaks well for the future prosperity of concrete. No missionary, home or foreign, can do more for the uplifting or bettering of humanity than to give the people of moderate means, or less, an everlasting, sanitary, artistic, fireproof, and economical building—a home to be a comfort and a pleasure to them all their lives. A home where the first cost is the last cost and which is just as satisfactory for their small outlay as is that of the wealthy for their large expenditure.

The story of Edison's poured house has made a deep impression on the people. More than any one thing, it has helped them to see with what wonderful facility concrete can be adapted to their needs in home building. There is something about a monolithic structure that gives them the impression of enduring forever. This to everybody is a very attractive feature. Even brick and stone, which have been considered our most enduring materials, no longer seem to quite measure up to this quality.

Not so very long ago, to build less than a 12-in. solid con-

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*C. R. Knapp Company, Philadelphia, Pa.

crete wall for even a one-story building was considered unsafe. Now a 6-in. reinforced wall is found to be of sufficient strength for any two-story house. This saving in labor and materials has greatly reduced the cost and helped very much towards making the small house possible in reinforced concrete. That the 6-in. wall will not show any dampness, if the concrete is properly mixed and placed, is proven by the stable erected for Mr. R. E. Griffiths, Haverford, Pa., over two years ago (Fig. 1). This stable has never shown any dampness, nor even condensation on the inner wall, although there has been heat in the stable at different times, during the two winters. For a summer home, inland or seashore, no plastering is necessary, thus the cost is reduced to a minimum.

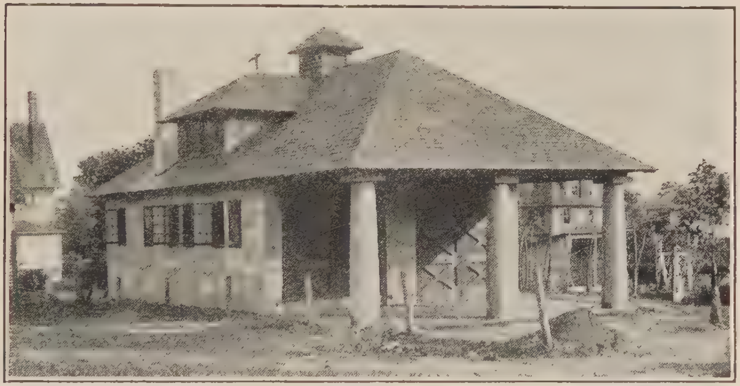

FIG. 1.—CONCRETE STABLE FOR R. E. GRIFFITHS, HAVERFORD, PA.

For an all-the-year house, in a warm climate, plaster directly on the wall, thereby the furring and lathing can be done away with. If the house is in a cold climate, I would advise that furring blocks be used, with the usual brown coat of plaster, as otherwise the wall may be too cold.

The wall that seems best suited for house construction and one which I believe has more advantages than any other is the hollow wall, consisting of two 4-in. walls with a 4-in. air space between. Both walls are reinforced with 3/8- or 1/2-in. steel rods spaced upright, at least every 18 ins. staggered and horizontal about 3 ft. apart. To tie the two walls together, leave a 3-in. web every 8 ft. and have metal ties every 2 1/2 ft. both ways.

The double wall insures against dampness and makes the house cool in summer and warm in winter. The air space may be utilized as a ventilating system, allowing each room to be ventilated without regard to any other room

In a concrete dairy barn (Fig. 2) erected for the Burn Brae Hospital, Primos, Pa., the past summer, the air space was used as a ventilating system. On each side of the building, near the floor and in line with the two roof ventilators, are 8 by 16-in. openings in the inner wall, with corresponding openings at the top of the

FIG. 2.—CONCRETE DAIRY BARN, BURN BRAE HOSPITAL, PRIMOS, PA.

wall, and from there continued to the roof ventilator, by boxing the rafter. There are a number of like openings in the outside wall, near the ground line, which have their corresponding openings in the inner wall, near the ceiling, thus creating a circulation that guarantees fresh, pure air, at all times.

One of the features of the Burn Brae stable, previously mentioned, was its frame roof, on an otherwise all-concrete building, which seemed wise for stable construction. It was reasoned that with a fireproof covering on the roof, it was fireproof from without. With this construction, should a fire start in the loft,

it would merely burn through the roof. This would give vent for the heat, making high temperature in the building impossible. No damage would result other than the loss of the roof and the contents of the loft. This method insures protection to the cattle on the first floor.

The extra cost of double walls is more than offset by the saving in being able to plaster directly on the concrete, using only one brown coat or the white putty coat. A beautiful and artistic effect may be had, by so erecting the inner walls and partition walls (if of concrete) that they do not require plastering or other covering. Concrete has sufficient merit to be treated frankly as such, instead of being hidden. Now introduce color and decoration, by using tiles and mosaic to give the needed life and relieve the monotony, but not for the purpose of hiding the concrete, which is exposed frankly where decorations do not occur. Then decoration will exercise its true function, by emphasizing, instead of hiding structural beauty. It is almost needless to say that, where this effect is sought, concrete, being a plastic material, is admirably adapted for this purpose. In this way we "decorate construction" and we do not "construct decoration." In many instances, the effect of the decoration is so great as to at once convince the uninstructed.

To make the air space, a system of collapsible cores is generally used. A better way, to my mind, is to make a concrete core, similar to a terra cotta partition tile, which is, of course, left in the wall. By using this method, from one to two inches of concrete may be saved, without affecting the strength. The core can be made on the job for about half what the terra cotta partition tile will cost.

The question of what kind of a finish to give a concrete wall is a matter of personal opinion, which is ever changing. The rough casting, or plastering of a wall, which has been the most common, is fast giving away to a more artistic treatment. A wire brush finish brings the coarser aggregates to the surface and gives a pleasing effect. A scrubbing brush, applied while the concrete is green, will erase the board marks and smooth up the wall to a sand-like finish. A carborundum stone is good for rubbing down a wall and with it you can get almost any texture. The finish that is pleasing to a large number of people, which is

really no treatment at all, is to leave the wall just as it comes from the forms, with all the board marks showing. An illustration of not only this simple method of surface treatment, but also the damp-proof character of a thoroughly well-made 6-in. wall, is the seashore house of Mrs. Gaston Daus, at Ocean City, N. J., within a block of the beach (Fig. 3). While most of the rooms are furred and plastered, there are several apartments in which the porch floor serves as a ceiling, in which the walls have not been

FIG. 3.—CONCRETE RESIDENCE OF MRS. GASTON DAUS, OCEAN CITY, N. J.

plastered. The house was built during the past summer and not the slightest sign of dampness or condensation has appeared. For weeks a pool of water lay on the porch before the top coat was put on, and no dampness appeared underneath. After protracted storms, the surface seemed to dry off instantly, while neighboring houses of brick, and even frame construction, retained evidences of moisture upon the outside, long after the concrete house had assumed its natural color. The owner and architect are more than pleased with the fact that they did not disturb the thin film of cement, which remained after the forms were removed and

to which they attribute great waterproofing virtue. They not only saved \$200 to \$300 for tool dressing, but have what they regard as a more artistic finish, because perfectly simple and natural, as well as indicative of the plastic nature of concrete. The architect, I am told, has said, were he to build another house, he would seek to emphasize this surface by using rough and unmatched lumber. The house is certainly pleasing with its substantial walls, porch columns and chimneys.

People are demanding fireproof houses to-day. They must, however, be educated to pay a higher first cost, if necessary, for

FIG. 4.—REINFORCED CONCRETE RESIDENCE AT POINT PLEASANT, N. J. TWO 4 IN. WALLS WITH 4 IN. AIR SPACE.

this class of construction and to realize that it is economical in the end, even at the increased cost. Repairs and insurance are practically eliminated. There is also a saving of 25 to 40 per cent. in the cost of heating, besides having a house that is thoroughly sanitary.

Large industrial plants are opening up a field of operation in building all-concrete houses. They desire these built near the works to rent to their employees. They must be fireproof and easily flushed after a tenant moves out.

In the matter of cost, we constantly see unfair comparisons

made between concrete and other materials. A dwelling of reinforced concrete from cellar to roof is expensive and immediately somebody exclaims, "My, your concrete house cost more than my brick house!" As a matter of fact our critic has not a brick house, in the sense that our house is concrete, he merely has a house with brick walls. Suppose he were to introduce the durable and fire-resisting features of the all-concrete house, by having his floors, stairways, and other features in brick. What would become of his theory as to excessive cost of concrete. It is, in this way, that the two materials should be compared. We can easily hold our own, when it comes to mere wall construction, and more than hold it, when our opponents seek materials of like durability for interiors and roofs.

One of the first things to do in building a concrete house is to get a concrete design, for, of all building material, concrete requires the most individual treatment. Many houses are built of concrete, after being drafted for brick, stone or frame, and this is the reason, some people say, they do not like the looks of a concrete house. The houses they have in mind probably would not appeal to us any more than they do to them. Concrete allowed to express itself in line of simple dignity, with now and then a touch of color, needs no promoter. But this constant forcing of concrete into imitations of brick, stone and frame designs, has been the great drawback to its acceptance as the ideal material for the construction of the individual and artistic house—the house that is different. Much of the beauty and effectiveness of concrete is lost by trying to disguise its real character. It is not a material to be ashamed of. Much of the richness of texture, just as it comes from the forms, with board marks showing, is sacrificed by being rubbed, dressed or plastered into smooth, characterless surfaces. Even devoid of any touch of color, the picturesque masses of masonry and the soft irregularity of its lines make it effective and entirely satisfying—a harmonious whole.

The attitude of the public is no longer in opposition to concrete. People are seeking information and are finding there is an artistic side which is very attractive. Within the past two or three years the use of cement and concrete has been a special feature in current literature. This is due to the fact that the wise publisher is striving to present subjects of interest to his readers.

He has discovered that the public is intensely interested in concrete as applied to practically every type of construction, and in consequence of this the daily and technical press and even popular magazines are making cement and its uses a special feature from day to day and month to month. Even such magazines as are distinctly literary in tone and purpose, have included cement construction in their contents, and when we look through the high class periodicals devoted to country and suburban life, practically every number has more or less extended reference to cement. No building material of ancient or modern times has received so much attention, and none so thoroughly merited it. Therefore our purpose should be, not only to disseminate all the information possible on this important subject, but to show our faith by conscientious and substantial work.

INEXPENSIVE HOMES OF REINFORCED CONCRETE.

By Milton Dana Morrill.*

What architectural style are we developing to-day? The Greeks developed the lintel type of architecture, following the natural shapes and sizes of available stone. The Romans built mostly in brick and developed the arch as a natural form for their material. What new type and style will be developed through the use of reinforced concrete? There must be a *concrete style.* We have already worked out the structural forms which seem best suited to the material, and possibly the best concrete buildings have been designed by engineers, as they have followed the simplest and most logical shapes, and have not been hampered by architectural precedent.

The architects are so wedded to traditional forms such as cornices, columns and arches, that they are likely to employ these in positions where they serve a decorative rather than a constructive function. Is there any reason why structures cannot be designed in the simplest and most natural forms for concrete, and still be beautiful in proportion, line, and color? Cannot honest construction be made decorative and beautiful without requiring a masque of false architectural detail or an imitation of materials? It has seemed to me that in cement work we have been designing in styles suited for wood or brick, and constructing in concrete with shapes unsuited and unnatural to the material in hand; this has, of course, made work difficult and expensive.

In my work on inexpensive homes, economy compelled me to put out of mind all architectural development, and to go back to first principles and to primitive homes. Houses as well as other structures need not be expensive to be beautiful. Good taste, proportion, and a good selection of materials and color are only necessary. The most costly buildings in this country are often the worst from an architectural and esthetic standpoint. Our early colonial homes are beautiful. Why? They are built of

* Architect, Washington, D. C.

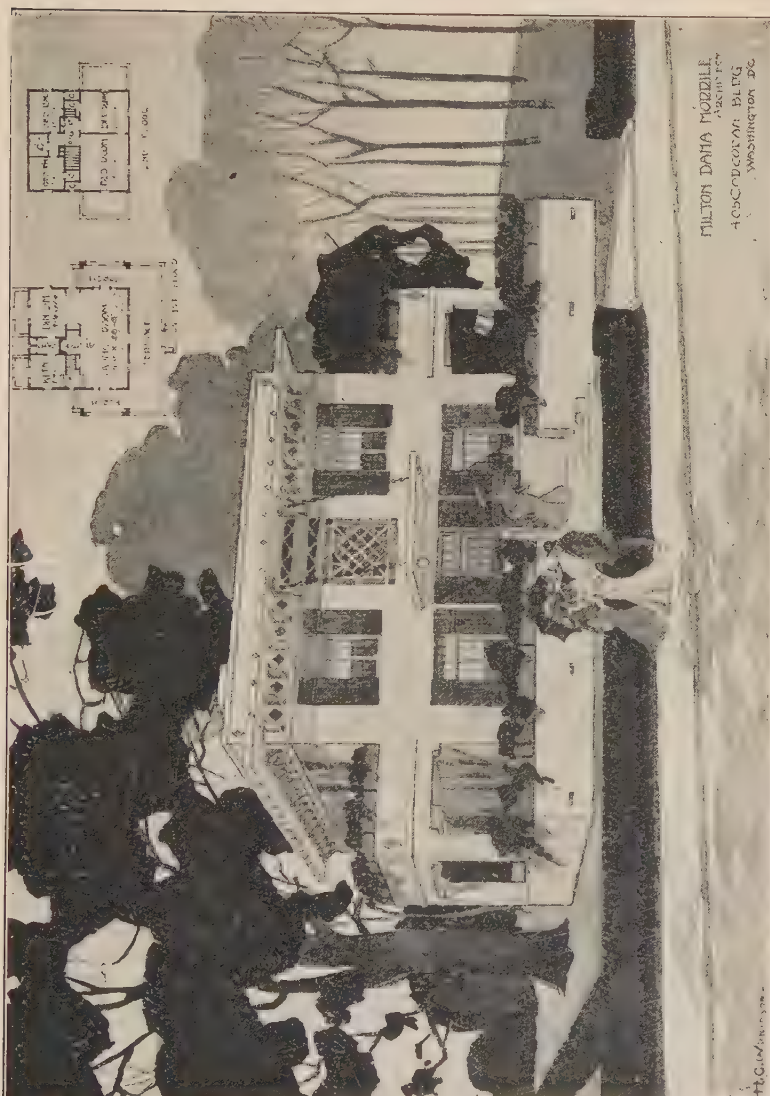

FIG. I.—DESIGN FOR A SEVEN-ROOM CONCRETE HOUSE.

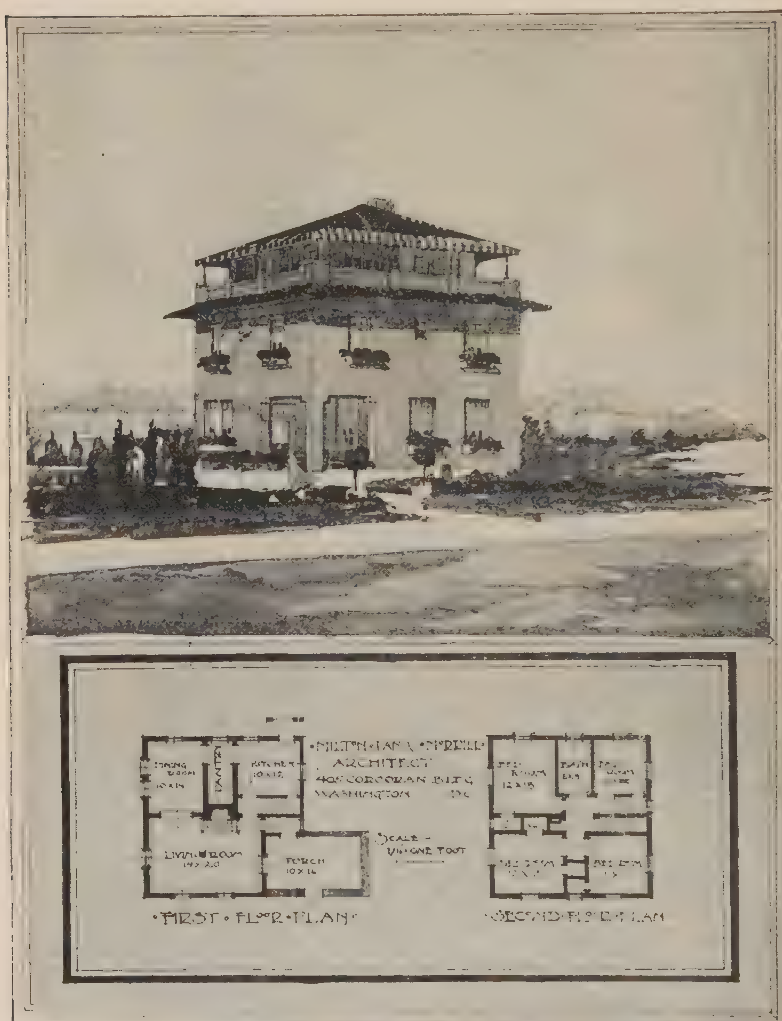

FIG. 2.—DESIGN FOR A SEVEN-ROOM CONCRETE HOUSE WITH ROOF GARDEN.

inexpensive material. Their simplicity and good taste is the open secret of their beauty.

The design of the small house would not seem such a great problem, however, it presents more difficulty than larger plans, as economy is of the first importance, although convenience, beauty and stability cannot be sacrificed. In literature the statement of a fact in the shortest, most concise and simple form takes great study, to eliminate and reduce expense without losing modern convenience and comfort, is the essence of scientific planning.

A seven-room house with large living room is shown in Fig. 1. Contract prices of $5,600.00 were received on this design, a frame structure could hardly be built for less.

It has been endeavored to combine in the designs illustrated the convenience of the apartment with the light, air, privacy and consequent health of the country. Passages and halls have been eliminated, leaving all space available for occupation. All rooms have lights on two sides. One chimney must serve, and convenience and economy in housework is of first importance. Figs. 2 and 3 show attractive seven-room concrete houses, Fig. 4 a six-room house. The science of living has been given little study, and many of us consider carefully in our work how we can economize in labor. But in our homes there is a great waste of effort and energy through unstudied plans.

Upon studying the problem of housing, I found that a box house was by far the most economic form which could be constructed enclosing a given space, as this form requires the least wall area. The box is also the most rigid and substantial, as is illustrated by those of pasteboard in daily use. While of a fragile and flimsy material, these become firm and substantial when reinforced at the corners.

The idea of a box-shaped house is not attractive to us, but why cannot this form be made beautiful. We see carved and decorated jewelry cabinets, which are exquisite; why can we not design attractive homes within similar lines, being guided more by the law of common sense, fitness and beauty, rather than by precedent, in following an architectural style, which at best cannot be suited in structural forms so changed.

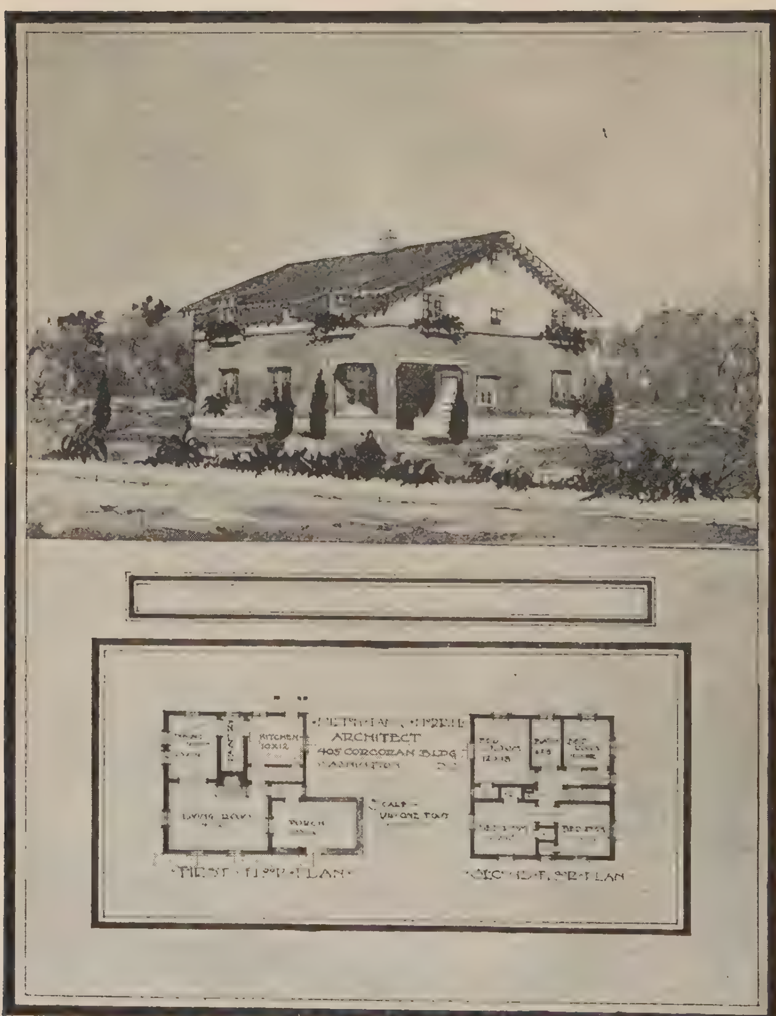

FIG. 3.—DESIGN FOR A SEVEN-ROOM SANITARY CONCRETE HOUSE.

Everything in daily use has been standardized, books are of uniform size, bookcases are arranged in unit sections and the same has been done with thousands of articles about us. The principle of standard forms has reduced cost and labor to a tremendous degree, and improved quality. Why cannot this same principle be applied to houses and homes? If standard homes can be built to advantage at wholesale, how important it is that these should be perfect in architecture and in plan. In all our cities contractors are building rows upon rows of houses, and in the majority of cases plans are not furnished by leading architects but they are bought from the man who will make them at cheapest price. Contractors will employ the best physician they can find for their families, but in these building operations the best architects are not employed because they will not compete with unstudied and inferior work. The public must see and live in these buildings which are not beautiful, and sometimes even offending to the eye. I believe that all our cities should have Art Commissions who would pass upon designs for fitness of appearance just as our health departments demand sanitary plans.

There are certain limitations to the economic use of concrete, and we might as well recognize these and design our work accordingly. When we come to intricate detail and curved surfaces, concrete work becomes difficult, on account of the necessary molds. Simple straight lines are ideal for this work, and after all they make the simplest and most attractive buildings (see Figs. 5 and 6).

I have adopted in all plans standard unit dimensions, so that drawings are reduced to mold diagrams, and after we have the design and follow our diagrams the building is bound to come out right. One of the plans is so arranged that the house can be built in sections, almost as a bookcase is put up, being complete in four, five, six, and seven-room houses, and arranged so that any number of rooms up to twelve can be made or added with no alterations. For a group of houses the fireplaces, stairways, sinks, ice-boxes, etc., are of a standard type and metal molds are made for these. To make an attractive mantel it is only necessary to lock together the standard molds and pour, the whole being made at a quarter the cost of our less substantial wood fixtures.

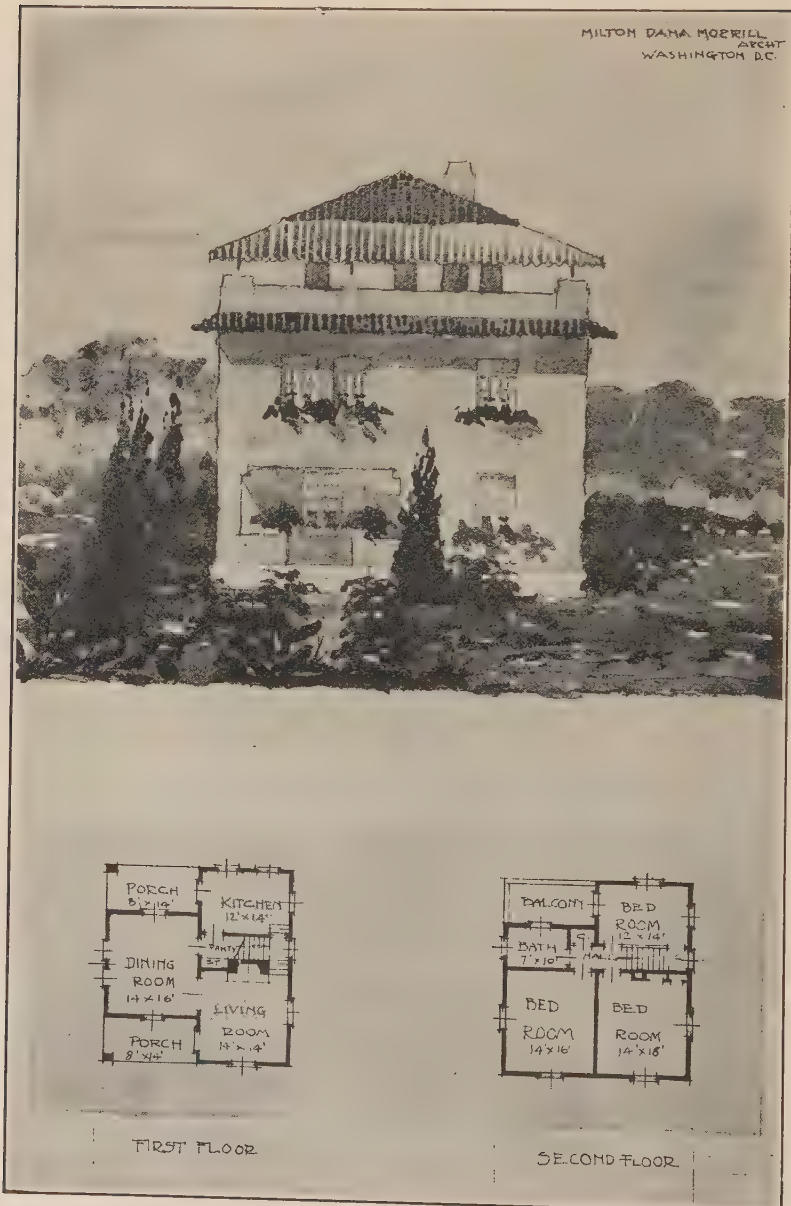

FIG. 4.—DESIGN FOR A SIX-ROOM CONCRETE HOUSE.

A simple design for a four-room and bath house with roof garden can be made of the cheapest possible construction and still be attractive. It can be arranged for a pitch roof, when the roof garden is not employed. In the preparation of these plans the designer has endeavored to invent homes where the inhabitant of the tenement can afford to live and where he and his family can enjoy two of the greatest gifts of God—good health and sunshine.

It is now realized that our hospitals can only relieve and prevent the communication of disease. They cannot stamp it out, and if future generations are to improve mentally, morally and physically, our people must live in healthy homes, and the city tenement cannot furnish these. A few years ago the expense of travel and time consumed made it imperative that the laboring classes should live near their work, but improved transportation and low fares have now increased the residence zone to many miles around our larger cities, and high land values and consequent high rents have reversed conditions, so that it is imperative that only inexpensive land shall be occupied for habitation.

The designs are almost primitive in their simplicity, but this simplicity adds rather than detracts from the appearance, and a group of these buildings, with their white walls, flower boxes, and inlaid marble block ornaments, would make a striking contrast to the usual inexpensive homes.

There is a great mental and physical improvement brought about through clean and beautiful homes, and a pride awakened which enters the entire life of the tenant. In the dark, unwholesome tenement there is little incentive for cleanliness in habits or in life, and a marked advance has been noted by a change to sanitary and attractive surroundings.

Fig. 7, shows the plan for model two-story, three-room apartments for the Octavia Hill Association of Philadelphia, Pa. The kitchen fixtures, sinks, ice-box and closet which are to be of cement in metal molds, occupy one end of the living room, so that by light washable curtains these can be screened when not in use. Bath rooms are interlocking in plan so that no space is lost.

The contractor's estimate in concrete was $900 per apartment, fire-proof and sanitary. In brick $1,100.00. These can rent

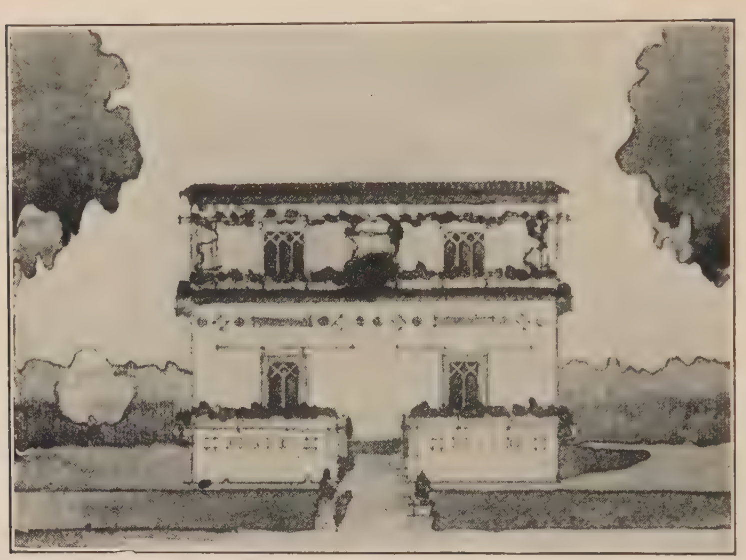

FIG. 5.—DESIGN FOR A SIX-ROOM WORKMAN'S COTTAGE.

FIG. 6.—DESIGN FOR A SEVEN-ROOM CONCRETE HOUSE.

for $8.00 to $10.00 per month. The group will comprise ninety buildings.

A three-room house is presented in Fig. 8, the large living room extending across the front with alcoves at each end fitted with couches and arranged so that these may be transformed into bedrooms by sliding curtains, an attractive open fireplace is directly opposite the entrance, the chimney also serving for kitchen range, a shower bath can be arranged in one of the closet spaces. Houses of this sort can be rented, giving a net 6 per cent. return on investment, at only $3.00 or $4.00 per month.

Fig. 9 presents a plan for a two-family house, the four-room apartment on the first floor opens on an attractive porch. The upstairs apartment opens on a front porch and separate entrance, each apartment has a bath.

Plans have been prepared for quite a group of the type shown in Fig. 10, to be constructed by the Mount Hope Finishing Company near Fall River, Mass. It will be noted that every room has windows on at least two sides, and all are arranged in such a way that they can be built as double houses or in block where land value prohibits the detached home.

While single homes can be constructed along the lines of the designs shown, the great economy obtained by wholesale building makes it desirable to construct in groups so that they can be almost entirely machine made. Just as in our clothing, tailor-made suits can only be afforded by those whose salaries warrant it, so in our homes, the specially designed and built house is only within the reach of a comparative few.

A competition for sanitary inexpensive workman's homes was held at the late International Congress on Prevention of Tuberculosis, when the house shown in Fig. 11, was awarded the first gold medal. The following are a few of the special and for the most part new features which have been incorporated in the design (see Fig. 12):

The coal is hoisted by a simple chain block, attached to a swinging davit and is dumped through a hole in the roof to a large pocket, from which it feeds by gravity into the fire-box of stove, the ashes falling into a pit and being removed from an outside door. This is simply the application of the equipment

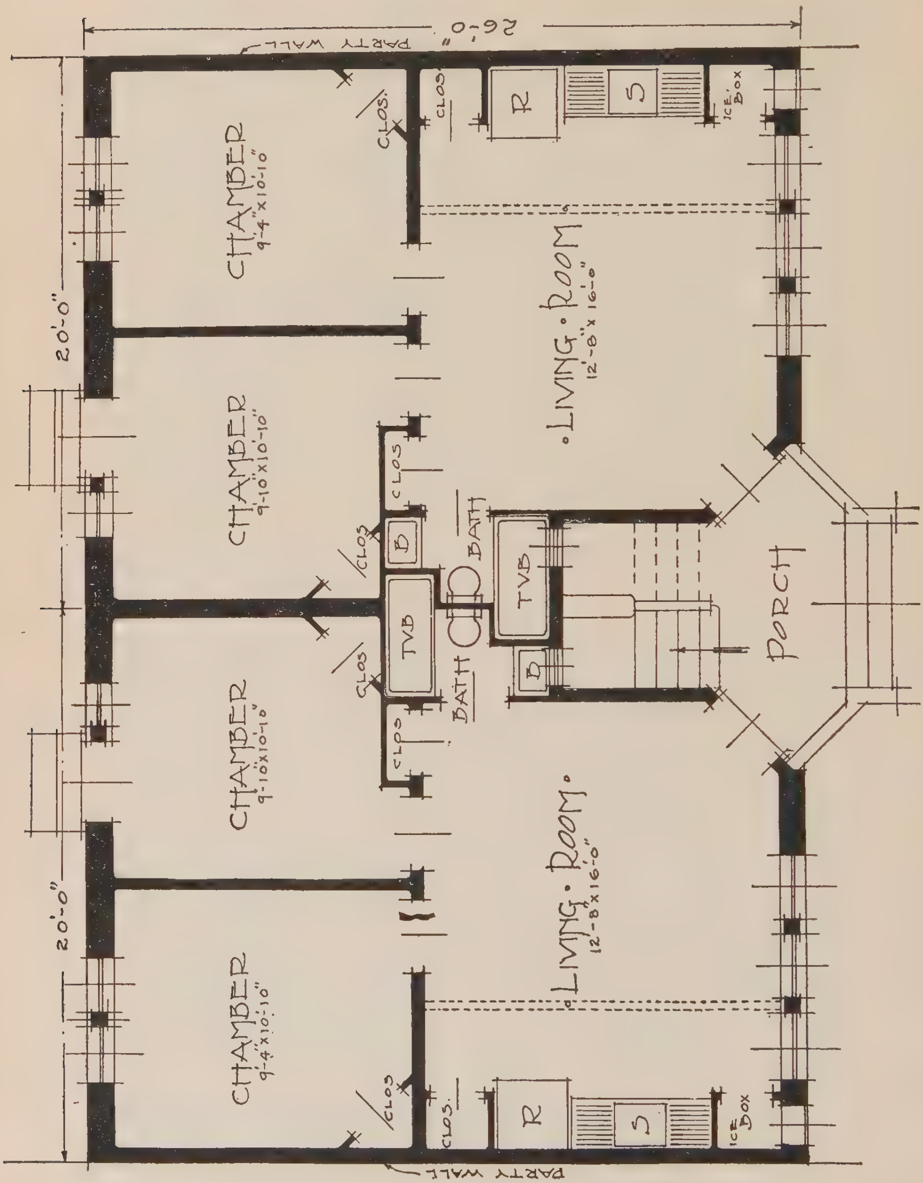

FIG. 7.—DESIGN FOR MODEL CONCRETE APARTMENTS FOR OCTAVIA HILL ASSOCIATION, PHILADELPHIA, PA.

of large plants to the homes. This stove combines in one compact fixture cooking range, house and hot water heater, and gas stove.

The garbage is placed in a cast iron chamber in smoke flue and after drying is dumped into fire-box by damper. Fireplaces

FIG. 8.—DESIGN FOR A THREE-ROOM CONCRETE COTTAGE FOR A WORKMAN.

in each room have flues about the smokestack forming a natural ventilation. The ice-box, which is filled from the outside, is arranged for use as a fresh-air closet, doing away with use of ice except in hot weather. This is also arranged to be flushed out with a hose.

The roof is of open cellular construction, cool in summer. An attractive feature of the house is the roof garden and sunroom forming an out-of-door bedroom, divided by use of movable screens. Window-boxes form an inexpensive and at the same time artistic decoration.

FIG. 9.—DESIGN FOR A TWO-FAMILY CONCRETE APARTMENT HOUSE.

We cast our walls for two story buildings 6 ins. in thickness, and you can realize how far a cubic yard goes in this thickness. With the steel molds we can place this for $5.00 per yard, so that a wall 9 ft. by 12 ft., the side of a room will cost but $10.00.

When the model house was first shown there were many skeptics as to the practicability of the scheme, and I thought that

the best plan was to construct a house along these lines, as an ocular demonstration is the only way to give definite proof. This house, which is in Brentwood, Maryland, near Washington, has very little wood except the window sash and doors (Fig. 13). The walls are 8 ins. in thickness, the floors are 4½ in. slabs, rein-

FIG. 10.—DESIGN FOR SEVEN-ROOM CONCRETE HOUSES, NEAR FALL RIVER, MASS.

forced. The molds were of wood made in standard sections, and one carload of Portland cement sufficed for construction. To thoroughly clean a room a hose is used, the cement floors, being graded to plugged tile spouts discharging on the lawn. An enclosure for the garbage pail is left under the wash tub (Fig. 14), which has an outside screen door for ventilation and

FIG. 11.—MODEL SANITARY WORKMAN'S HOME.

removal. This is arranged to be flushed out. A small wood strip is laid in the border so that rugs or carpet can be tacked in place, if desired. All corners are coved, and all fixtures are bracketed from the wall, which leaves no places for the shelter of dust, vermin or insects, and facilitates cleaning.

The possible omission of insurance and repairs and their general indestructible character makes this type of building especially suitable for rented houses.

The waste from the kitchen range heats the house through circulation of hot water, being so built that in summer an inside firebox cuts off the house heating system.

All fixtures, such as kitchen sinks and washtubs, lavatory and bath tubs, are cast in concrete, and given a very smooth cement finish. For the water supply a concrete tank is built in the top of the bath room which is filled from a small force pump at the kitchen sink. In some of my plans I have graded the roof to a sand box filter connecting with the tank, so that rain water may also be stored and used.

The windows are of a casement type swinging out, with no trim but with a stencil border (Fig. 15), sash being hinged to simple metal strips, which form a weather tight joint. In some buildings my plans contemplate a window sliding sideways into a wall pocket. The screen being locked to the sash so when the latter is opened the screen follows, closing the opening.

The building has no exterior ornamentation, as the flowers and vines in the window boxes and the lattice will give the best of decoration and color. Why do we have flowers and ornaments of stone when we can have real flowers which are more beautiful and decorative? These flower-boxes (Fig. 16), of course they are of concrete, now contain small cedar trees which we gathered near the site, and the vines are the wild honeysuckle, which grows in such fragrant tangles all about.

It is difficult to base an estimate of cost on construction of this first house, since the molds and the superintendence time has been charged against it, but it is safe to estimate that these houses can be built in groups at between $200 and $300 per room.

In the construction of concrete houses, I have found that in some light work the cost of lumber and carpentry labor for molds

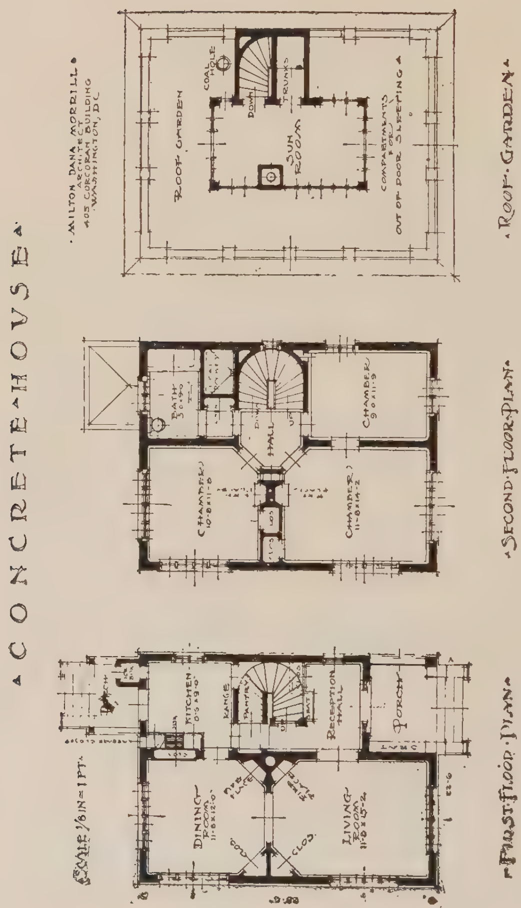

FIG. 12.—PLAN OF MODEL HOME SHOWN IN FIG. 11.

was three-fourths the total cost. It is necessary that this expense should be reduced or eliminated, if we are to build in this material. I searched the market in this connection, for a standard sectional

FIG. 13.—CONCRETE HOUSE, BRENTWOOD, MD.

metal mold equipment and found several good types but none exactly suiting my requirements. The simple equipment (Fig. 17) is the result of many months of experimental work, and should, I believe, do much to reduce the cost of concrete construc-

tion, since it practically eliminates carpentry and lumber waste. The mold plates are pressed from 12 gauge sheet steel into flanged sections 24 ins. square. Upon the completion of the footing the plates are locked to the cement spacing-blocks (Fig. 18), furnishing a trough, into which the concrete is poured. The cement spacing blocks are of course left in the wall and the plates are locked to these by a key, which is afterwards removed. Wherever four

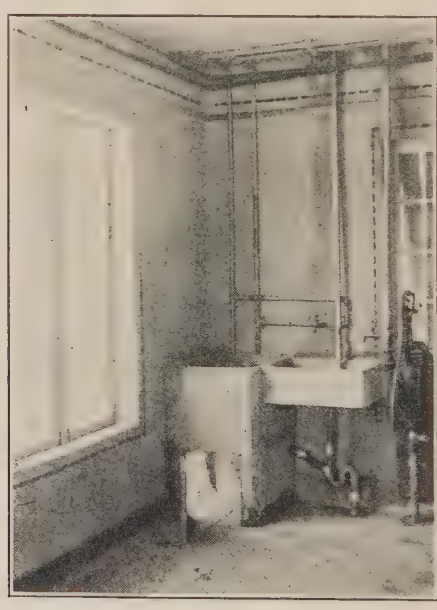

FIG. 14.—CORNER OF KITCHEN, CONCRETE HOUSE, BRENTWOOD, MD.

corners join a cuff engages, wedges the plates together and draws them to perfect alignment on the inside. The whole stands very rigid and firm when erected, and in experimental work, I have not found it difficult to keep work plumb, as the corners give alignment. The plates are two tiers in height, each tier being clamped together in series, and attached by a hinged rod so that the lower tier is unlocked and swung to its new position on top and locked, there being few loose parts to fall.

The whole equipment for house construction has only ten

FIG. 15.

FIG. 16.

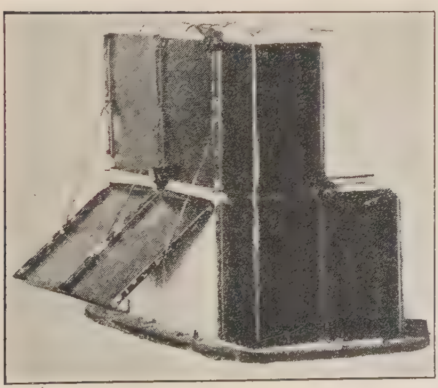

FIG. 17.

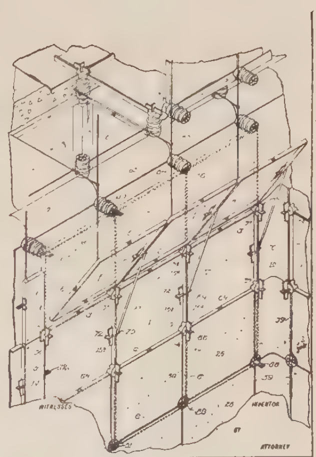

FIG. 18.

parts, and as it costs about $800.00 and can be used indefinitely, the cost per house is not great.

These plates are locked together in the same way for the floors (Fig. 18), the spacing blocks here give the exact thickness of slab, and reinforcement rods are placed and accurately secured to these blocks by bending a heavy wire which is cast in each block with end protruding for this purpose. To give a smooth and even floor surface, a wet mix is poured in, and the plates are slid in place on top and locked to spacing blocks, and wedged

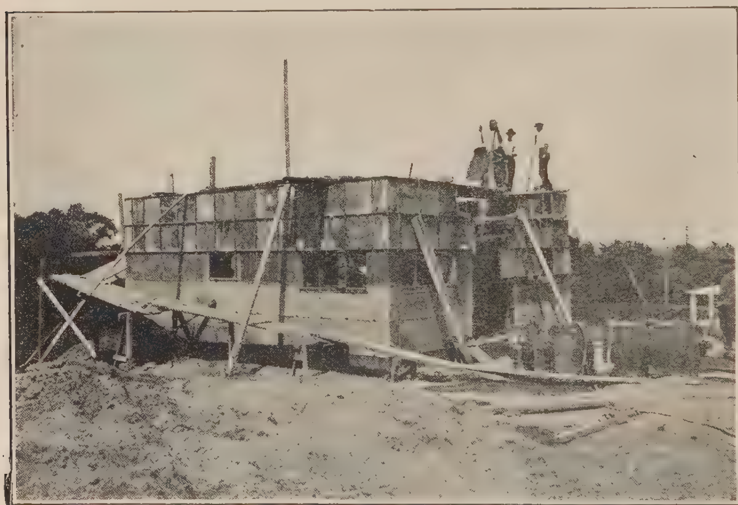

FIG. 19.—CONCRETE HOUSE IN COURSE OF CONSTRUCTION.

down until the surplus mix is squeezed out in front, this should do away largely with expensive labor in cement finishing. For the floors cement spacing blocks are cast with projecting flanges so that they will give considerable support to the slab and reinforcement and permit the lower plates to be removed after three days. A post being wedged and blocked up under each spacer gives supports only 24 ins. apart.

Fig. 19 shows a building in course of construction. The work of one week has brought the forms to the position shown, the pouring of concrete being in progress. An inclined runway

FIG. 20.—CONCRETE STATION AND HOUSES AT VIRGINIA HIGHLANDS, MD.

is built entirely around the structure as the building goes up. The window frames are shown as dropped in place.

I found upon experiment that a slight ridge or pattern was formed by the joining of the mold plates and spacing blocks were found to be of slightly different color. I have treated this as wall decoration, and with the rosettes cast on the spacing blocks, an extremely interesting pattern is formed, and it is possible to leave the wall without further finish inside or out, unless a brush coating is applied to give a more uniform color, and as a safeguard against dampness. As the plates are cleaned and greased each time they are raised, and as the concrete is a very wet mix, an extremely smooth surface is obtainable, requiring no plaster, the economy is, I believe, apparent.

The station and the first two houses at the new cement suburb, Virginia Highlands, Md., are shown in Fig. 20. The fountain, seats, flower boxes, signs, and much of the garden furniture has been constructed of cement. The station was poured in the molds above described, the concrete consisting of cement, sand and cinders. The walls, roofs and partitions are of concrete. The cinders were used in order to show the factory owners the possibility of constructing with the refuse from their own furnaces, healthy and inexpensive homes for their employees.

DISCUSSION

Mr. F. B. Gilbreth.—I would like to ask if, in his experience, Mr. Morrill has not found that where the metal molds are flanged and not brought to a very sharp angle, leaving a slight projection on the work when the forms are taken off, the work eventually shows a distinct marking, even after the projection has been removed. A building, with fluted columns, was erected some ten years ago and the architects decided that they did not like the fluting. While the concrete was still comparatively green stone cutters removed the fluting. To-day you can still see the marks of the flutings just as plainly as if the concrete was over them. We have also noticed this in our work, and for that reason have gone to a large expense to have the flanges on our metal molds made with the sharpest angle possible. Mr. Gilbreth.

I would also like to get some information regarding the condensation on the inside of a thin wall of a concrete house, where there is no provision for a continuous air space.

Mr. Milton D. Morrill.—I believe as far as possible we should make our equipment so as to leave the wall as it is intended to remain, and for that reason I studied the exterior leaving this pattern. I imagine it would be difficult, although I have not progressed far enough to state whether it is absolutely impossible to cover up and erase the mold lines. I believe, however, by using a carborundum or emery brick, planing off the surface and coating, there is no reason why this should not give a smooth surface. Mr. Morrill.

In regard to condensation, that is a question which has come up and has worried me more or less. I have found no difficulty in a thin wall from condensation. The reason I believe is that the wall changes in temperature as the weather conditions change, and that with a 2 or 3 ft. wall there will always be condensation. With a thin wall, only 6 to 8 ins., I never experienced any trouble from this cause.

A question upon which I would very much like to get some

Mr. Morrill. information is, the conductivity of concrete. Opinion seems to be very divergent and nobody seems to know exactly how much concrete will conduct heat. I have found my buildings very cool in summer and warm in winter, but I am not satisfied with these few examples; I would like the opinion of other men along this line.

Mr. Gilbreth. MR. GILBRETH.—Mr. Charles L. Norton, of the Massachusetts Institute of Technology, has been conducting, for about two years, a series of experiments on the subject conductivity of concrete.

Mr. Mensch. MR. L. J. MENSCH.—Mr. Morrill states that there is less condensation with a thin wall than with a thick wall. You can see condensation in every room of a manufacturing building having thin concrete slabs. There is more condensation if you use a corrugated iron roof, because the change in the temperature is so much faster. The thinner the wall, the more condensation. I built a large plant with 4 in. walls at the request of the owner. I proposed hollow blocks for the walls, inasmuch as concrete walls were wanted; but the 4 in. walls were used and the condensation gives lots of trouble.

I do not believe that cheap concrete houses will be built by means of metal molds. About six months ago I made a proposition to a cement plant in California to build houses of the bungalow type with hollow concrete walls, 12 ins. thick, consisting of inside walls 1 1/2 ins., and outside walls 2 ins. thick, at a price which was the same as that for frame buildings. If the difficulty of cleaning metal molds is considered, and the loss by indenting and other accidents, such a house would be considerably more expensive than a frame house. Furthermore I think there are many methods by which concrete houses can be built much more ornamental, without practically any additional cost. The whole wall can be made on the ground and lifted by any common method. You can finish the surface of the walls with cement and make them absolutely waterproof. You can decorate by imbedding tiles or anything else at a very low cost. I figured in several instances that I could put up such hollow walls, cement finished, at a cost of 15 cts. per sq. ft., which you certainly cannot do by using metal forms.

Mr. Ernest McCullough.—Mr. Morrill has frankly recognized the material with which he is dealing, and the plans show a boldness of design and strength in their lines that will certainly tend to popularize concrete as a building material. The cost at which he is erecting the houses makes them practically comparable with first quality brick houses and they will have greater permanence, at the same time allowing better opportunity for decorative work. **Mr. McCullough.**

In the treatment of the exterior surfaces I think there has been a frank recognition of the material in permitting a design created by the forms to remain on the surface. Wherever there is a projection of the surface between the forms it is an indication that some of the moisture has escaped. I do not believe it is possible to remove the projections. Why should an effort be made to get an absolutely smooth surface by rubbing down the lines, as in that way the watertightness of the exterior wall is destroyed? In brick work the most artistic buildings are those which accentuate the mortar joints. While we know it is almost impossible to remove the lines showing the marking between the forms, they can not be avoided in actual structural work. I have tried to improve the appearance of some buildings on the outside by rubbing down the surface and then giving it a surfacing of paint. It looks well in dry weather, but just as soon as the air become surcharged with moisture the lines show up.

I would like to mention another class of concrete houses. Two years ago I prepared plans for a group of buildings for a mining company in which galvanized metal studding was used, the framework erected precisely the same as a wooden house, and the exterior and interior are covered with metal lath plastered. They are bunk houses for one, two and three families of miners. The mines being closed down in the winter, of course, the houses are vacated and in the fall it is proposed to fumigate them by burning sulphur over night or so. After this sulphur has been burned all the doors and windows are to be opened and the houses washed out with water. The cost of such buildings at that point is in the neighborhood of about $175.00 for a room 16 ft. square, 8 ft. 6 ins. high.

THE USE OF CONCRETE IN FARM BUILDINGS FROM A SANITARY POINT OF VIEW.

By S. Cunningham, Jr.*

The requirements for sanitary construction of farm buildings make concrete and cement the most useful material for floors and walls and even for roofs and ceilings when expense does not prohibit its use. Most boards of health which undertake to regulate the production of milk sold under their jurisdiction require or advise the use of cement for floors in cow stables, and specify also that the walls and ceilings must be tight, clean, and free from dust-catching surfaces, which evidently suggest the use of cement or hard plaster finishes. At present stables are usually built of wood, but concrete in blocks or cast in forms is being used more each year, and there are already a large number of barns scattered throughout the country which show in a highly developed way the best uses of concrete. The fire-proof and permanent qualities of this material are powerful inducements of themselves towards its use. The ease with which the buildings may be kept clean, the good health of the animals stabled therein, and the possibility of producing clean milk with a minimum of labor all increase the weight of argument in behalf of concrete. Figs. 1, 2, 3 and 4 show good examples of concrete farm buildings.

For floors concrete shows practically no wear from use; it is water tight, non-absorbent and sanitary, and if sufficient bedding is used it makes a satisfactory material for animals to stand and lie upon. When the floor is upon earth fill it is advisable to put a layer of sand 6 ins. or more thick under it, especially in damp locations, and to place under the stalls themselves a waterproofing layer, such as two or three layers of tar paper on a base of cement, well brushed with coal tar pitch. This prevents dampness from drawing up through the concrete and makes a warmer floor. The waterproofing should be covered with a thickness of concrete and cement surfacing of at least

*Architect, New York, N. Y.

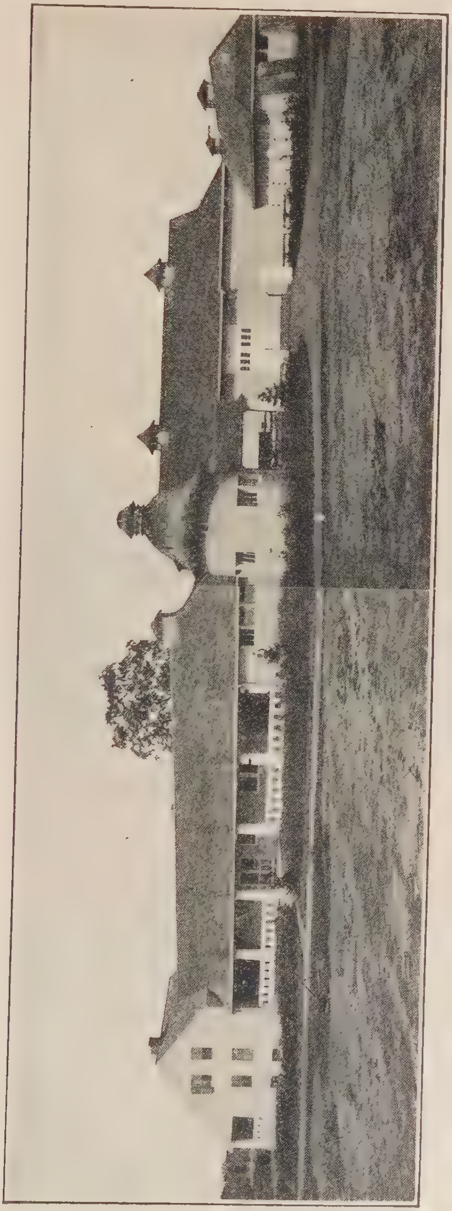

FIG. 1.—GROUP OF CONCRETE FARM BUILDINGS NEAR RHINEBECK, N. Y.

3 ins. for cow stalls and 4 ins. for horse stalls. It is possible to use less than this for cow stalls (but not advisable in horse stalls) by putting down metal lath over the waterproofing, nailing through to the concrete beneath to hold the lath firm, then plastering the lath with heavy coat of cement mortar mixed 1 to 2, 1 in. thick, or more. All stall surfaces and passages to be used by animals should be left rough, finished with a wooden float, or a float covered with carpet. Figs. 5 and 6 illustrate the use of cement floors.

Many farmers are prejudiced against a cement floor; they

FIG. 2.—CONCRETE BLOCK FARM STABLE, BLACKSMITH SHOP, WHEELWRIGHT, ETC., AT LENOX, MASS.

think it cold, causing stiffness and rheumatism in stock and udder troubles in cows. If sufficient bedding is used, this objection is removed. The good points of a concrete floor outweigh all supposed disadvantages. If a wooden surface is preferred for the stalls, a platform may be made of 2-in. oak, chestnut, or spruce, creosoted to prevent absorption of urine. The platform should be built in sections, one or two for each stall, set in a pan formed of cement, so as to be readily removable for cleaning or renewal. An excellent floor may be made of the creosoted wood paving blocks, such as are used in street paving. They are about 3 ins. thick, and set with the grain vertical on a concrete base, and hot asphalt poured on to fill all cracks. Asphalt softens less

from animal heat than coal tar pitch, and does not work out of the joints to stick to the hide of the animals. There are some special floors that are good. Asphalt mixed with granulated cork in a layer about ¾ in. thick makes a floor that is warm and gives a good foothold. Many of the patent floors are either cold, or those made with a mixture of sawdust absorb the urine, and swell and come up from the concrete base; even those that stand an occasional wetting will not stand the continued action of the urine.

The feed mangers (see Figs. 6 and 7) in front of the cow stalls should be low and of just sufficient depth to allow also of

FIG. 3.—CONCRETE FARM STABLE AT WHITE PLAINS, N. Y.

watering the cows. Six inches is deep enough. Watering in this way at regular periods has been proven the best for cows. They drink more, and at more suitable intervals than when they have water always before them in individual drinking pots, which are, besides, very difficult to keep clean. It is often impossible to turn a large herd out to water from a trough in the yard, and the continuous manger into which water may be admitted from a large hydrant forms an easy and cleanly method of watering. The water being shallow and the mangers the temperature of the stable, the chill is taken off the water even in severe weather, while the water in a yard trough, unless special means

are taken to warm it, is often too cold for the cows to drink deeply. The low mangers offer the advantage of feeding practically on the floor. The passage in front should be as high as the front of the manger, so that any feed thrown out by the cows may be easily swept back within their reach.

The stalls are made short enough (the length depending on the kind of stock) to have the droppings from the cows fall in the gutter, which should be about 16 ins. wide and 8 or 10 ins. deep, so that when the cows lie down they will not get foul. The stalls should have a pitch of not more than 1 to 1½

FIG. 4.—CONCRETE DAIRY AND CREAMERY AT WHITE PLAINS, N. Y.

ins. to the gutter. Too large a pitch brings the weight of the calf and udder too much on the hind legs.

All feed passages, mangers and gutters should have a smooth, hard, troweled finish, which it is easier to keep clean than a float finish.

Cement partitions have been used between stalls both for cows and horses, but iron pipe cow stalls are better, with metal stanchions to confine the animals. For horse stalls (Fig. 8) partitions built with iron posts and ramps and 2 x 8 in. yellow pine slats, separated about 1 in., are very stiff and give good ventilation, making them cool in summer. Horse stall floors should be treated as for cow stalls. They should pitch about 2 ins. toward

the gutter. The gutter in this case should be very shallow, not over 1½ ins. deep, 16 ins. wide, and uncovered. There will be more wear on horse stall floors, so they should be laid more carefully with this in view.

Where the floors join the walls, and in fact all interior angles in the stable should be coved or rounded on a 3 in. radius, to prevent corners for the collection of dirt. A small detail, but one that makes a great difference in the cleanliness of a stable.

Concrete in many forms has been used for walls. The object to be attained is a hard, smooth wall surface, insulated

FIG. 5.—INTERIOR OF STABLE FOR 36 HORSES AT WHITE PLAINS, N. Y.

as well as possible from changes of external temperature. It is, of course, not difficult to prevent moisture coming through from the outside, but condensation of moisture inside is more difficult to avoid. Concrete blocks with air spaces, cored reinforced walls, and solid walls furred with wood or metal and finished with plaster on metal lath, or lined with plastered partition tile or concrete blocks with a space between the two walls, are methods used for insulation.

Dampness in a stable is very often a sign of poor ventilation. A cow gives off from the lungs and skin from 8 to 10 lbs. of water per 24 hours, which must be removed to prevent the air

becoming saturated. In such an event, if the wall surfaces are but slightly colder than the dew point or condensation temperature, water will form on them, and under bad conditions they will be dripping. Fortunately the amount of air required for healthful condition of breathing is in excess of that necessary to remove the moisture except in certain conditions. When warm, moist weather succeeds much colder temperatures the walls do not respond immediately, and condensation occurs. If the air space in the walls is filled with chopped straw, sawdust, or planer chips,

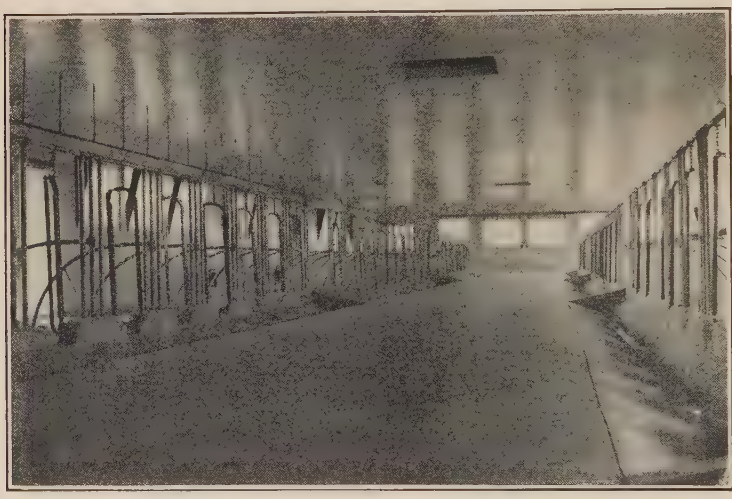

FIG. 6.—INTERIOR OF COW BARN AT AMHERST, MASS.

the insulation is improved. In wooden frame structures with inner walls of hard plaster on lath, condensation takes place unless the walls between the studs are filled as above noted, and even smooth wooden sheathing painted or varnished will be moist, though it is not so apparent. The objection, then, is not one that holds against concrete alone.

The subject of ventilation is very important, and definite means should be provided to insure a proper circulation of air. The old farm buildings which were scarcely more than rough sheds were full of cracks through which the air could pass. Modern concrete barns leave no such chances for haphazard ven-

tilation, and with 40 cows in a barn of 20,000 cu. ft. capacity, each cow requiring five or six times the amount of air necessary for a man, the ventilation must be positive and adequate to make the conditions healthful. It has been the usual experience, where condensation was taking place, it could often be proven by actual test that the circulation of air was insufficient for the health of

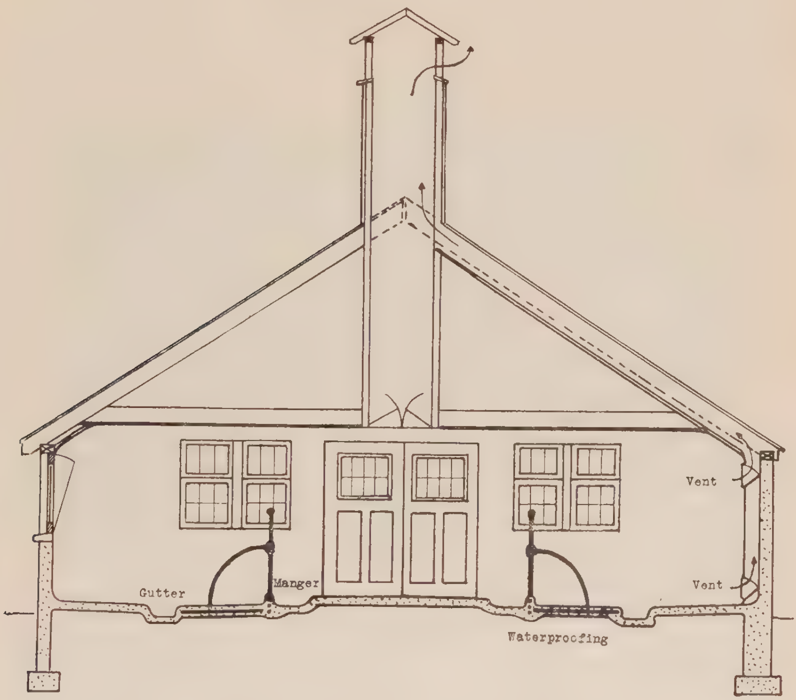

FIG. 7.—SECTION THROUGH COW BARN.

the animals, due to the ventilators being kept closed. There are several good systems of natural ventilation, and no barn should be constructed without one of these, or other proper means to supply fresh air. In northern climates the barns should be made small, about 500 or 600 cu. ft. capacity per animal is about right. Such a building is easier to keep warm, and yet is large enough to allow of proper ventilation without causing

severe draughts. The ventilating flues may be built of concrete, tall enough to act on the principle of a chimney, and to cause circulation by difference in weight of the column of warm air within and cold air outside (see Fig. 7).

For piggeries (Fig. 9) the use of cement in construction

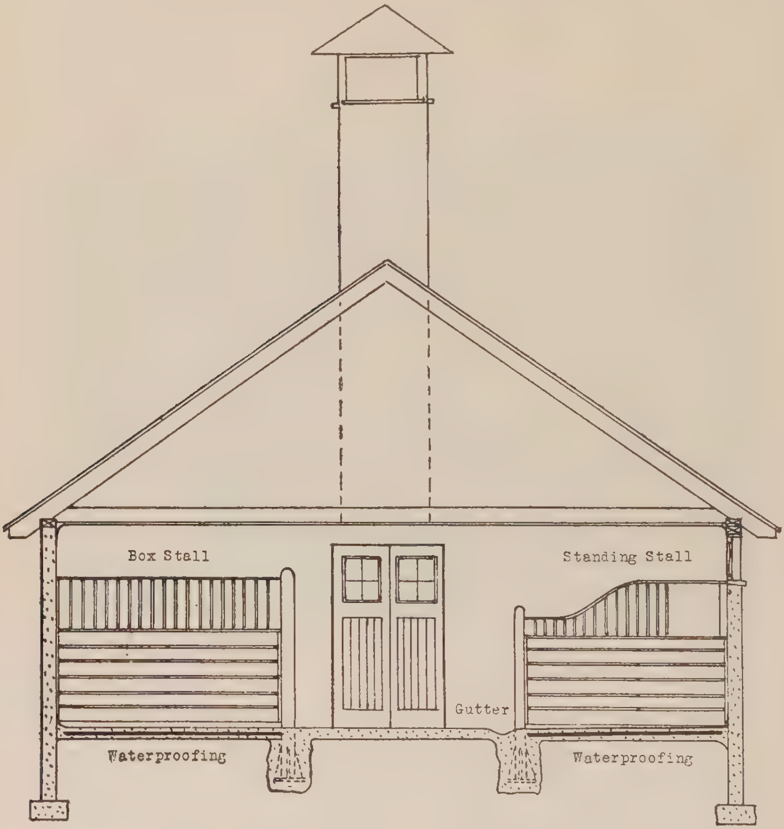

FIG. 8.—SECTION THROUGH HORSE STABLE.

is as advisable as for stables. They are much more likely to be neglected and allowed to become foul, and a cement finish is so easily washed down that there is no excuse for such condition. Pigs are liable to contagious diseases, and a building that can be hosed out and disinfected and having no absorbent materials

or cracks to harbor bacteria, can be used again with no danger of the infection spreading. This applies as well to cow stables.

Almost all large milk farms depend in a great degree on ensilage for feed. A cement silo is equal to the best that can be built for storing ensilage. The proper preservation of ensilage depends on keeping it packed tight to exclude the air, with smooth walls, so that as the ensilage settles it does not loosen at the walls to admit air there. Structurally, cement silos are practically everlasting. The acids existing in the fermented juice of the corn

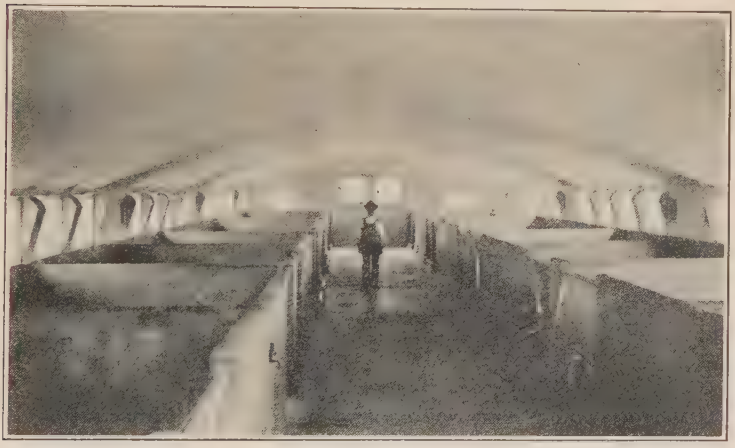

FIG. 9.—INTERIOR OF CONCRETE PIGGERY AT WHITE PLAINS, N. Y. NO WOOD USED IN THIS BUILDING EXCEPT FOR THE DOORS AND SASH.

attack the surface to a very slight degree only, and cement walls either solid or cored prevent the freezing of ensilage better than a wooden stave silo, the form most commonly used. The freezing not only spoils that part of the ensilage lying within a few inches of the wall, but by causing the frozen ensilage to cling to the wall, the even settlement is interfered with, and part of the remainder spoiled by the admission of air.

For poultry houses concrete makes a warm tight building that will exclude rats and other animals preying on chickens, and one that can be kept clean for the prevention of lice. The floors in laying house pens should be made 6 ins. below the

level of the door sills, and filled with cut straw or gravel for scratching. This can be renewed as often as necessary to keep them clean.

Where manure is stored and not spread on the fields as soon as produced, a tight pit, covered or uncovered, is necessary to prevent the leaching away by the weather of the soluble parts of the manure, which are the most valuable as fertilizer. Concrete offers an excellent material of which to construct such pits. The floors may be pitched to a sump pit in one corner, and the

FIG. 10.—CONCRETE BLOCK COW BARN, DAIRY, HAYBARN AND SILO AT AMHERST, MASS..

liquid pumped out and applied to the fields, using a sprinkling cart for this purpose.

The production of clean milk requires the best sanitary conditions in the buildings in which the milk is handled, as well as in the cow stable where it is produced. The extensive use of concrete floors and smooth plastered walls with coves in all angles will make such a dairy easy to keep clean, but offers no particular requirements in the way of sanitary design. In this connection, however, it has been found that wooden soled shoes offer a much better way of keeping the feet of the workers dry and warm than do rubber, which are heavy, unhealthful and wear

out quickly on the concrete floors. The use of live steam and hot water hosebibbs offers an increased advantage in keeping such buildings clean and sterile.

One of the most important points in favor of concrete for farm buildings is the fireproofness of the structure as well as their action as firewalls to prevent the spread of the fire to other buildings. A notable case of this kind is well illustrated in Figs. 10 and 11. The fire occurred in the hay barn, which has a concrete block firewall between it and the cow barn, but is framed with wood. The only loss was the hay barn and the silo roof as shown in Fig. 11.

FIG. 11.—FARM BUILDINGS SHOWN IN FIG. 10 AFTER FIRE IN HAYBARN.

For greenhouses, hotbeds, and wherever wood in contact with earth has been found to rot out, concrete has been substituted with the expected advantages. Tables in greenhouses can be easily designed and built of it, making them permanent and avoiding a large item of expense in renewals. No objection has been discovered to its use in this way from any unfavorable action on the plant life. In fact, it forms a better protection than wood from possible variations of temperature.

The fact that concrete can be kept clean more easily than any other material in common use is its greatest recommendation for its use in farm buildings. The realization that health to a

very great degree depends on cleanliness is as true for farm stock as it is for mankind. Good laboring help is difficult to obtain on most farms, and anything that contributes to the reduction of labor necessary to keep the surroundings clean is bound to grow rapidly in favor on that score alone, especially since no valid objections can be substantiated to its use in connection with stock or farm products.

DEVELOPMENT OF CONCRETE ROAD CONSTRUCTION.

By Fred R. Charles.*

The City of Richmond, Ind., cannot claim to have a large amount of concrete roadways, but it constructed some of the first concrete street pavements. The first roadway, laid in 1896, now has nearly 14 years of life and usefulness to its credit, and is still continuing its service without having cost one cent for repairs. In truth this was a small beginning, and owing to the excellent character of the macadam streets, Richmond has been backward in constructing permanent pavements. Nevertheless this first concrete roadway has so abundantly justified its existence, that for the last eight or ten years it has been added to annually. There was nothing especially remarkable about the construction of this pavement, except that extreme care was used in all the processes, particularly the seemingly minor ones. We endeavor in all our cement work to watch carefully the small matters, remembering the proverb, "that perfection is made up of trifles, but perfection is no trifle." The natural soil under this first pavement is gravel, so that no sub-base was required. The concrete was proportioned 1-2-5, deposited 5 ins. thick after ramming, with a top surface 1 in. thick, proportioned 1-2. The wearing course was cut into blocks about 5 ft. square and the surface pitted with an ordinary lug roller.

In subsequent work, various plans have been used. The principal variations consist in the material for aggregate, thickness of concrete, with and without a top surface, thickness of the latter, size of blocks, thickness of joints and material used therefor. One roadway was cut in blocks 8 to 10 ft. square; another 30 to 40 ft. square; all joints between the blocks, both cross and longitudinally, are 1 in. wide and filled with paving pitch. The defect of this method consists of the chipping of the concrete

*City Engineer, Richmond, Ind.

edges at these joints, principally the longitudinal ones. Our experience seems to show the blocks should be as large as possible in order to reduce the number of joints, and that the joints should be as thin as can be made. On the other hand, we find that blocks 10 to 15 ft. square are about as large as can be made without developing temperature cracks in our climate. These latter, however, apparently do not injure the pavement beyond detracting from its appearance, as cracks that have existed for years show no enlarging, and the pavement up to and over the cracks is as solid as elsewhere. I do not know whether experiments have been made to ascertain the proper size of blocks for use in different climates, or places with a certain average range of temperature. Corrugating or grooving the surface is also objectionable for the same reasons as are the joints; the edges of the grooves afford an opportunity for the concrete to chip and spawl off by the action of the hoofs of horses, etc. Also the grooves catch and collect the dirt, interfering with the cleanliness of the pavement, and rendering it more difficult to sweep. Possibly the corrugations afford slightly better foothold for horses, but I think even here the advantage is exaggerated.

We obtain a very good surface by using 1 part cement to 2 parts hard-grained, coarse sand, screened through a No. 4 screen. The work is troweled down to remove all holes, air spaces, etc., and "raised" with a cork or wood float, giving a rough, gritty surface. On this horses can maintain their footing as securely as on a cement-filled brick, an asphalt, or wooden block pavement when damp. For ordinary traffic pavement we find excellent results are secured by the use of 5 ins. of 1-2-5 concrete, and a top surface 1½ ins. thick, mixed 1 to 2. For automobile travel nothing could be more satisfactory.

It should be unnecessary to say that care must be used in selecting good aggregates, proportioning properly to reduce voids to a minimum, and securing good workmanship in all the operations of mixing, placing and finishing the work. I am a firm believer in a wet mix, for this, as well as for most other concrete work. Place this concrete on a well prepared foundation, using suitable straight edges and templates cut to the required crown of the street; tamp or jostle to make a compact mass, leaving the sur-

face rough to provide attachment for the top layer; cut joints through the concrete every 10 to 15 ft., and fill with sand. Before the concrete begins to set place thereon the top surface, composed of one part cement to two parts hard, coarse sand, trowel and float, cutting joints directly over those in the concrete Use a small radius jointer to leave as thin a joint as possible, and finally finish by means of a float, leaving the surface as rough as possible. This gives a roadway very suitable for our use. For heavier traffic, 6 ins. of concrete and a 2-in. top surface is advantageous.

We have also had good results by making the pavement homogeneous, that is, without the top surface. Make the concrete somewhat richer in cement, and quite wet. Tamp until free mortar flushes to the top, then finish with trowel and float. For this purpose the concrete should be free from large stones, as with a large stone at the surface, if one end becomes worn loose, a large leverage is afforded to tear the remainder of the stone from the concrete.

The disadvantage of concrete is its lack of toughness, whereby exposed edges of joints and corrugations are prone to chip and wear off. For this reason joints ought to be reduced to a minimum, and especially longitudinal joints should be eliminated wherever possible. Another defect urged against concrete is its lack of elasticity. This contention does not seem to be well founded, as concrete is not the only non-elastic pavement. Brick on a concrete foundation and with a cement filler seems to be about as unyielding and non-elastic as any roadway could be. Of course for horses some elasticity is desirable, but in view of the increasing numbers of motor vehicles, this quality is not so essential to so many users as formerly.

The present laws of the State of Indiana, while passed avowedly in the interests of the asphalt paving industry, ought to bring about the increased use of concrete roadways. For example, plans must be made for a foundation suitable for any kind of "a modern city pavement," which foundation naturally will be concrete. Then the specifications must include and bids be received for four different paving materials to go on top of this concrete foundation. After receipts of bids the property owners have

the right to determine which one of the four shall be adopted, and since cheapness usually appeals to the average property owner, asphalt often wins the day, because with the same foundation specified for each pavement, the top surface of asphalt can be put on at less cost than brick. Here is the chance for concrete paving. Put down a foundation suitable for any kind of pavement, viz., 5 or 6 in. deep of concrete, mixed, placed and jointed as above suggested; then before this concrete begins to set place thereon the "paving material," consisting of the wearing surface, 1½ or 2 ins. thick, mixed one part cement and two parts sand. You will then have a pavement that can compete with any other in price, and will cost less in maintenance, will give a cleanly, sanitary effect, and will come as near to satisfying the public as you can ever hope to satisfy that exacting personage.

DISCUSSION.

Mr. W. M. Ketchin.—In Connecticut we are very much interested in the development of road construction, concrete or otherwise, and have tried various materials and methods. There are one or two points on which I should like further information. I understood that a wet mixture was used and the joints filled with sand, yet the top dressing was placed before the rough concrete began to set. If the forms were removed or the joints cut for sand filling while the cement was soft would not the sides come in and close the joint? **Mr. Ketchin.**

I have found in my experimenting that in our climate blocks over 5 sq. ft. are liable to give a great deal of trouble. In putting down the rough concrete I used 3/16 in. iron separators and when it has set enough I pull these out, being careful to mark the exact position on the forms. Then the top dressing is placed and while it is soft cut through to the rough concrete with a jointer, this making a complete separation.

Mr. Fred. R. Charles:—We mark off the joints, then cut through the concrete with what we call a concrete cutter, anything which will make a groove, then immediately fill with sand and tamp the concrete on both sides so that possibly some cement will go through the sand. It will not make an absolutely separate joint but so nearly that it will answer all requirements. Then we immediately put the top dressing on, and having marked the location of the joints in the base we cut them through the top surface immediately over the joints in the base. **Mr. Charles.**

Mr. E. S. Larned.—I would like to suggest that if the difficulty mentioned is of common experience that it could be overcome to a great extent by building alternate sections of the roadway. In the work described by Mr. Charles, the blocks are from 10 to 15 ft. long, and in the process of construction the idea would be to put in every other block, the screeds being set to the finished grade, and, after placing the concrete base to the required grade, the top or wearing surface could be placed imme- **Mr. Larned**

Mr. Larned. diately or shortly afterward and finished. The screeds would be left in position until the concrete had hardened and then the intermediate blocks could be placed, using the finished surface on either side instead of the screed to bring the work to the correct grade. The old concrete having hardened, it would not be subject to injury in this operation.

Mr. Ketchin. MR. KETCHIN.—I never attempt to place the top on hardened concrete unless it is absolutely necessary. I once placed a 1 in. top on a cement floor that had set for two months. Before placing, however, I carefully cleaned the surface with diluted muriatic acid, taking great care to remove all dirt. Afterwards I had occasion to cut a hole through this floor and found it hardened as one piece. In fact, pieces would break or chip off as one piece. It required great care in cleaning the old work and I consider it poor practice.

NOTES ON THE USE AND COST OF CONCRETE BLOCKS IN ROADWAY CONSTRUCTION.

By George C. Wright.*

This paper is in the nature of a description of a system of road surfacing which is new in this country, and is taken in the main from a report of Mr. J. T. McClintock, made to the Highway Commission of New York State.

Macadam used to say that if one could get stone broken into cubes of uniform size of about 1 in. square and once get them laid the ideal road would be secured. The increasing difficulty of maintaining a macadam surface composed of irregular shaped fragments of varying size under the conditions of rapidly moving vehicles emphasizes the importance of the remark of the father of stone roads.

The general use of Portland cement for most purposes of construction naturally leads to the thought of the possibility of taking stones as they come from the crusher in irregular shapes and square them up by means of Portland cement. The low price at which Portland cement can be secured brings the cost of such treatment within reason. It appeared probable that if the wearing surface of a highway could consist of 2-in. cubes placed closely together and made of either Portland cement with gravel or broken stone, or vitrified shale, or asphaltic concrete, or bitulithic concrete, or iron furnace slag, that the following results might be obtained: Comparative freedom from dust, smoothness of surface, good footing for horses and wheels, pliability permitting of changes in the base due to freezing and thawing, and movement due to the contraction and expansion.

As these cubes could be supported on any suitable local stone or gravel the cost per mile for first-class road would evidently be very much below that of ordinary paving brick and more lasting than any of the asphaltic or bitulithic mixtures, and further, the maintenance would be simplified and reduced in cost.

* Consulting Engineer, Rochester, N. Y.

The State Highway Commission authorized the expenditure of $2,250 for the purpose of making a preliminary demonstration, with the following results: On the Ridge Road northwest of the city of Rochester, N. Y., the original trap rock surface 2 ins. thick was worn completely off at the center and nearly so at the sides of the 16-ft. macadam roadway, leaving exposed a good solid lower course of rather large size broken Medina sandstone, resting on a good gravel foundation.

FIG. 1.—VIEW OF 2-IN. CONCRETE CUBES ON EXPERIMENTAL ROAD.

The existing surface was somewhat rough and knobby, and over this was spread as thin a layer as possible of screened gravel, which was rolled down with a 12-ton roller, so that in spots it was 2 ins. thick and in other spaces over the knobs it was of no measurable thickness. The resulting surface had a crown of about 4 ins. in 16-ft. width. On this bed so prepared was placed directly a wearing coat of 2-in. cubes for a width of 15 ft., being laid close together by hand, with the edges held up temporarily by 2-in. planks laid lengthwise with the road (Fig. 1*). On the cubes

* Acknowledgment is made to the *Engineering News* for the illustrations used in this paper.—ED.

was spread a small amount of fine, somewhat loamy gravel, which was broomed in, after which the heavy roller was slowly passed over the whole of the surface, forcing the cubes to take a full bearing on the supporting gravel. The edges and roller wheel was supported by the planks, then the side-planks were pulled up and moved ahead and coarse gravel ¾ in. to 1½ ins. in size was placed along the sides next to the cubes on the shoulder for a width of about 2 ft. Outside of this a finer gravel was spread,

FIG. 2.—CUBES IN PLACE ON ROAD..

feathered off to a width of about 3 ft., more of the fine loamy gravel was spread on the top and broomed and flushed in until the space between the cubes was thoroughly filled, the gravel on the shoulders was wet and the whole surface thoroughly rolled with the heavy roller (Fig. 2).

A stretch of road 1,800 ft. long was surfaced with cubes. On 1,600 ft., Portland cement gravel concrete cubes were used, on 200 ft. vitrified shale cubes 2¼ ins. in size were used. For a length of 100 ft. a concrete sunken curb 6 x 9 ins. in dimension was used in place of the gravel shoulders. On 100 ft. in length

the joints between the cubes were filled with Portland cement grout instead of the fine loamy gravel. For 60 ft. on which the joints were filled with the fine gravel, and light asphaltic road oil was sprinkled over.

A machine for making cubes which is an adaptation of the ordinary cement brick machine was used. This machine made 68 cubes at one operation, resting on a wooden tray, and the tray was carefully placed on a drying rack without disturbing the freshly made cubes. The cubes remained in racks 24 hours and were then dumped in a pile. This pile was thoroughly sprinkled twice each day.

The number of cubes made was about 7,000 upon the first day, but within a few days the same gang was able to make with ease 26,000 cubes. Various sizes of screens were tried from ½ to 2-in., but it was found that the ½-in. screen gave a product that could best be handled in the machine. Experience showed that the concrete had to be rather dry in order to avoid settling and bulging of the cubes before the concrete set. Seven men and a foreman did all the work. The amount of cement used averaged 2.2 bbls. to a cu. yd. of concrete. The area covered with cement cubes was 2,652 sq. yds., upon which was laid all of the 730,000 cubes manufactured, except about 5,000 kept for repairs. The cost of cement cubes laid was as follows:

Cement, 0.88 bbls.	$0.121
Cost of factory	0.107
Labor of manufacture	0.161
Gravel, 50c. per cu. yd.	0.024
Carting	0.027
Laying	0.072
Total cost per sq. yd. laid	$0.512

There were placed on shoulders 219 cu. yds. of gravel covering 1,800 sq. yds. costing $2.12 per cu. yd. rolled in place, or 26 cts. per sq. yd.

In considering these figures as the basis for estimating cost it is obvious that there might be reductions made in cost of cement by using a reduced quantity, and in reduced cost of carting, the cost of the factory might be distributed over many more

square yards, the cost of labor by use of concrete mixer and other labor saving devices. The cost of gravel in pit is usually nearer 10 cts. per cu. yd. than 50 cts., which was paid here. The cost of laying was very much reduced as the men became experienced, and this could be still further reduced by paying for it on the basis of piece work.

REPORT OF COMMITTEE ON ROADWAYS, SIDEWALKS AND FLOORS.

The Committee has prepared and submits for consideration proposed Standard Specifications* for Concrete Street Pavements and Concrete Curb and Gutter, including both Combination Curb and Gutter and Curb without Gutter. These Specifications were formulated after taking into consideration all the data which we could accumulate. We do not ask that they be accepted as presented, but invite discussion which may result in revisions which will make them worthy of being adopted by this Association as Standards.

There was considerable discussion on the Standard Specifications for Portland Cement Sidewalks presented by the Committee last year. After studying this discussion and considering other data available the Committee has prepared a revised specification* which is submitted herewith, with the hope that with the revisions which may result from a free discussion this year a Standard may be adopted, the character of which will justify us in leaving it undisturbed for a number of years.

Respectfully submitted,

C. W. Boynton, *Chairman*,
H. B. Andrews,
A. C. Birnie,
W. W. Schouler,
A. E. Snodgrass.

* The specifications as revised and adopted appear in the following pages.—Ed,

NATIONAL ASSOCIATION OF CEMENT USERS.

PHILADELPHIA, PA.

STANDARD SPECIFICATIONS FOR PORTLAND CEMENT SIDEWALKS.

REVISED FEBRUARY, 1910

MATERIALS.

The cement shall meet the requirements of the Standard Specifications for Portland Cement of the American Society for Testing Materials, and adopted by this Association (Standard No. 1). **1. Cement.**

Fine aggregates shall consist of sand, crushed stone or gravel screenings, graded from fine to coarse, passing when dry a screen having one-quarter (¼) inch diameter holes, shall be preferably of siliceous materials, clean, coarse, free from loam, vegetable or other deleterious matter, and not more than three (3) per cent. shall pass a sieve having one hundred (100) meshes per linear inch. **2. Fine Aggregates.**

Mortars composed of one (1) part Portland cement and three (3) parts fine aggregate by weight when made into briquets, shall show a tensile strength of at least seventy (70) per cent. of the strength of 1 : 3 mortar of the same consistency made with the same cement and standard Ottawa sand.

Coarse aggregates shall consist of inert material, graded in size, such as crushed stone or gravel, which is retained on a screen having one-quarter (¼) inch diameter holes, shall be clean, hard, durable, and free from all deleterious matter. Aggregates containing soft, flat or elongated particles shall be excluded. **3. Course Aggregates.**

The maximum size of the coarse aggregate shall be such that it will not separate from the mortar in laying and will not prevent the concrete fully filling all parts of the forms. The size of the aggregate shall be such as to pass a one and one-quarter (1¼) inch ring.

4. Natural Mixed Aggregates. Natural deposits of sand and gravel usually being out of balance shall be screened and remixed to agree with the proportions specified under Base.

5. Sub-Base. Only clean, hard, suitable materials shall be used, not exceeding four (4) inches in the largest dimension.

6. Water. Water shall be clean, free from oil, acid, strong alkalies or vegetable matter.

SUB-GRADE.*

7. Slope. The sub-grade shall have a slope toward the curb of not less than one-half (½) inch per foot.

8. Depth. (*a*) *The sub-grade shall not be less than twelve (12) inches below the finished surface of the walk.

(*b*) The sub-grade shall not be less than four (4) inches below the finished surface of the walk.

9. Depth of Layers. All soft or spongy places shall be removed, and all depressions filled with suitable material, which shall be thoroughly compacted by flooding and tamping in layers not exceeding six (6) inches in thickness.

10. Deep Fills. When a fill exceeding one (1) foot in thickness is required to bring the walk to grade, it shall be made in a manner satisfactory to the engineer. The top of all fills shall extend beyond the walk on each side at least one (1) foot, and the sides shall have a slope of not less than one to one and one-half (1 : 1½).

11. Drainage. When required, a suitable drainage system shall be installed and connected with sewers or other drains indicated by the engineer.

SUB-BASE.*

12. Width; Thickness. On the sub-grade and at least two (2) inches beyond the inner and outer lines of the walk shall be spread a suitable

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* When a sub-base is required eliminate paragraph 8 *b*.
When a sub-base is not required eliminate paragraphs 5, 8 *a*, 12 and 13.
Unless paragraph 8 *a* is eliminated 8 *b* is void.

material hereinbefore specified, which shall be rammed thoroughly to a surface at least four (4) inches below the final grade of the walk. On fills the sub-base shall extend the full width of the fill and the sides shall have the same slope as the sides of the fill.

While compacting the sub-base the material shall be kept thoroughly wet and shall be in that condition when the concrete is deposited. **13. Wetting.**

FORMS.

Forms shall be free from warp, and of sufficient strength to resist springing out of shape. All mortar and dirt shall be removed from forms that have been previously used. **14. Material.**

The forms shall be well staked to the established lines and grades, and their upper edges shall have sufficient rise from the curb to provide proper drainage; but shall not exceed three-eights (3/8) of an inch per foot, except where such rise parallels the length of the walk. **15. Setting.**

In every fifty (50) lineal feet of walk at least a one-half (1/2) inch expansion joint shall be provided. Any means which will provide this will be accepted. **16. Expansion Joint.**

All forms shall be wetted thoroughly before any material is deposited against them. **17. Wetting.**

SLABS.

The slabs or independently divided blocks when not reinforced shall not have an area of more than thirty-six (36) square feet or have any dimension greater than six (6) feet. Slabs of more than thirty-six (36) square feet shall be reinforced with one-quarter (1/4) inch steel rods, spaced not more than nine (9) inches apart, or with smaller rods or fabric of equal strength. **18. Size**

The thickness of the slab for residence districts shall be not less than four (4) inches and for business districts not less than five (5) inches. **19. Thickness.**

BASE.

The concrete for the base shall be so proportioned that the cement shall overfill the voids in the fine aggregate by at least five **20. Proportions.**

(5) per cent., and the mortar shall overfill the voids in the coarse aggregate by at least ten (10) per cent. The proportions shall not exceed one (1) part cement to eight (8) parts fine and coarse aggregates.

When the voids are not determined the concrete shall be composed of one (1) part cement, three (3) parts fine aggregate and five (5) parts coarse aggregate.

11. Measuring. The method of measuring the materials for the concrete, including water, shall be one which will insure separate uniform proportions at all times. A bag of cement (94 pounds) shall be considered to have a volume of one (1) cubic foot.

12. Mixing. The ingredients of the concrete shall be thoroughly mixed dry, sufficient water added to obtain the desired consistency, and the mixing continued until the materials are uniformly distributed and the mass is uniform in color and homogeneous.

13. Machine Mixing. When the conditions will permit, a machine mixer of a type which insures the uniform proportioning of the materials throughout the mass shall be used.

14. Hand Mixing. When it is necessary to mix by hand, the mixing shall be on a water-tight platform and the materials shall be turned until they are homogeneous in appearance and color.

15. Consistency. The materials shall be mixed wet enough to produce a concrete of a consistency that will flush readily under light tamping, but which can be handled without causing a separation of the coarse aggregate from the mortar.

16. Retempering. Retempering, that is, remixing with additional water, mortar or concrete that has partially hardened, will not be permitted.

17. Placing. The forms shall be filled and the concrete struck off and tamped down sufficiently to receive a top of the required thickness. After the addition of water, the mixture shall be handled rapidly to the place of final deposit. Under no circumstances shall concrete be used that has partially hardened.

Concrete shall not be mixed or deposited when the temperature is below freezing unless special precautions are taken to avoid the use of materials containing frost, and to protect the work against frost until thoroughly hardened.

Workmen shall not be permitted to walk on freshly laid concrete, and where sand or dust collects on the base it shall be removed carefully before the wearing surface is applied.

WEARING SURFACE.

The wearing surface shall be mixed of one (1) part cement and not more than two (2) parts fine aggregate, with sufficient water to produce a consistency which will not require tamping but which can be easily spread into position with a straight edge. The mortar for the wearing surface shall be mixed in a mortar box. **28. Mixing.**

The wearing surface shall be spread on the base immediately after mixing, and in no case shall more than fifty (50) minutes elapse between the time the concrete for the base is mixed and the wearing surface is placed. **29. Depositing.**

The wearing surface of a walk in a residence district shall be at least three-quarters (¾) of an inch thick, and in a business district at least one (1) inch thick. **30. Thickness.**

After the wearing surface has been worked to an approximately true plane the slab markings shall be made. If joints have been provided in the base during construction or have been cut in the base prior to spreading the wearing surface, the markings shall be made with a tool which will cut entirely through the surface and completely separate the wearing surface of adjacent slabs. If joints have not been provided in the base they must be made with a tool which will cut through to the sub-base and completely separate adjacent slabs. **31. Marking**

The slabs shall be rounded on all surface edges to a radius of about one-half (½) inch. **32. Edges.**

When required, the surface shall be troweled smooth. The application of neat cement to the surface in order to hasten the hardening is prohibited. **33. Troweling**

On grades exceeding eight (8) per cent. the surface shall be roughened. This may be done by the use of a groover, toothed roller, brush, float or other suitable tool. **34. Roughening Wearing Surface.**

When coloring matter is required it shall be mixed dry with the sand and cement, which have been previously mixed dry, until the mixture is of a uniform color. The quantity and quality of the coloring shall be such as not to impair the strength of the wearing surface. **35. Color.**

When completed, the walk shall be kept moist and protected from traffic and the elements for at least three days. **36. Protection.**

SINGLE COAT WORK.

With the following exceptions the specifications covering two-coat work will apply to single coat work:

37. **Proportions.** The proportions shall not exceed one (1) part cement, two (2) parts fine aggregate and three (3) parts coarse aggregate.

38. **Consistency.** The materials shall be mixed wet enough to produce concrete of a consistency which will not permit of tamping but which can be handled without causing a separation of the coarse aggregate from the mortar.

39. **Placing and Finishing.** The form shall be filled, the concrete struck off, and the coarse particles forced with a suitable tool to a depth below the surface which will permit of finishing the walk as specified for two-coat work.

National Association of Cement Users.

PHILADELPHIA, PA.

STANDARD SPECIFICATIONS FOR CONCRETE ROAD AND STREET PAVEMENTS.

Adopted February 1910.

MATERIALS.

The cement shall meet the requirements of the Standard Specifications for Portland Cement of the American Society for Testing Materials, and adopted by this Association (Standard No. 1). **1. Cement**

Fine aggregates shall consist of sand, crushed stone or gravel screenings, graded from fine to coarse, passing when dry a screen having one-quarter (¼) inch diameter holes, shall be preferably of siliceous materials, clean, coarse, free from loam, vegetable or other deleterious matter, and not more than three (3) per cent. shall pass a sieve having one hundred (100) meshes per linear inch. **2. Fine Aggregates.**

Mortars composed of one (1) part Portland cement and three (3) parts fine aggregate by weight when made into briquets, shall show a tensile strength of at least seventy (70) per cent. of the strength of 1 : 3 mortar of the same consistency made with the same cement and standard Ottawa sand.

Coarse aggregates shall consist of inert material, graded in size, such as crushed stone or gravel, which is retained on a screen having one-quarter (¼) inch diameter holes, shall be clean, hard, durable, and free from all deleterious matter. Aggregates containing soft, flat or elongated particles shall be excluded. **3. Coarse Aggregates.**

The maximum size of the coarse aggregate shall be such

that it will not separate from the mortar in laying and the size of the coarse aggregate shall be such as to pass a one and one-half (1½) inch ring.

4. Natural Mixed Aggregates. Natural deposits of sand and gravel usually being out of balance, shall be screened and remixed to agree with the proportions specified under Base.

5. Sub-base. Only clean, hard, suitable material shall be used, not exceeding four (4) inches in the largest dimension.

6. Water. Water shall be clean, free from oil, acid, strong alkalies or vegetable matter.

7. Expansion Joint Filler. The expansion joint filler shall be a suitable elastic, waterproof compound that will not become soft and run out in hot weather or hard and brittle and chip out in cold weather.

SUB-GRADE.

8. Section. The sub-grade shall have a rise at the center of not more than one one-hundredth (1/100) of the width of the pavement.

9. Depth. (*a*)* The sub-grade shall not be less than thirteen and one-half (13½) inches below the finished surface of the pavement.

(*b*) The sub-grade shall not be less than seven and one-half (7½) inches below the finished surface of the pavement.

10. Depth of Layers. All soft or spongy places shall be removed, and all depressions filled with a suitable material, which shall be thoroughly compacted in layers not exceeding six (6) inches in thickness.

11. Deep Fills. When a fill exceeding one (1) foot in thickness is required to bring the pavement to grade, it shall be made in a manner satisfactory to the engineer.

12. Drainage. When required, a suitable drainage system shall be installed and connected with sewers or other drains indicated by the engineer.

SUB-BASE.*

13 Thickness. On the sub-grade shall be spread a suitable material hereinbefore specified which shall be rolled or rammed thoroughly to a surface at least seven and one-half (7½) inches below the finished surface of the pavement.

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* When a sub-base is required eliminate paragraph 9 *b*.
When a sub-base is not required eliminate paragraphs 5, 13, 14 and 9 *a*.
Unless 9 *a* is eliminated 9 *b* is void.

14. **Wet Material.** While compacting the sub-base the material shall be kept thoroughly wet and shall be in that condition when the concrete is deposited.

FORMS.

15. **Material.** Forms shall be free from warp, and of sufficient strength to resist springing out of shape. All mortar and dirt shall be removed from forms that have been previously used.

16. **Setting.** The forms shall be well staked to the established lines and grades.

17. **Wetting.** All forms shall be wetted thoroughly before any material is deposited against them.

EXPANSION JOINTS.

18. **Width and Location.** Expansion joints one-half (½) inch wide shall be placed at least every fifty (50) feet and between the curb or edge of the gutter and the pavement.

BASE.

19. **Proportions.** The concrete for the base shall be so proportioned that the cement shall overfill the voids in the fine aggregate by at least five (5) per cent., and the mortar shall overfill the voids in the coarse aggregate by at least ten (10) per cent. The proportions shall not exceed one (1) part cement to eight (8) parts fine and coarse aggregates.

When the voids are not determined the concrete shall have the proportions of one (1) part cement, three (3) parts fine aggregate and five (5) parts coarse aggregate.

20. **Measuring.** The method of measuring the materials for the concrete, including water, shall be one which will insure separate uniform proportions at all times. A bag of cement (94 pounds) shall be considered to have a volume of one (1) cubic foot.

21. **Mixing.** The ingredients of the concrete shall be thoroughly mixed dry, sufficient water added to obtain the desired consistency, and the mixing continued until the materials are uniformly distributed and the mass is uniform in color and homogeneous.

22. Machine Mixing. When the conditions will permit, a machine mixer of a type which insures the uniform proportioning of the materials throughout the mass shall be used.

23. Hand Mixing. When it is necessary to mix by hand, the mixing shall be on a water-tight platform and the materials shall be turned until they are homogeneous in appearance and color.

24. Consistency The materials shall be mixed wet enough to produce a concrete of a consistency that will flush readily under light tamping, but which can be handled without causing a separation of the coarse aggregate from the mortar and which will not creep towards the curb or sag out of place when deposited and lightly tamped.

25. Retempering. Retempering, that is, remixing with additional water, mortar or concrete that has partially hardened, will not be permitted.

26. Placing. The concrete shall be deposited in strips extending across the full width of the area paved. After the addition of water the mixture shall be handled rapidly to the place of final deposit. Under no circumstances shall concrete be used that has partly hardened.

Concrete shall not be mixed or deposited when the temperature is below freezing unless special precautions are taken to avoid the use of materials containing frost, and to protect the work against frost until thoroughly hardened.

Workmen shall not be permitted to walk on freshly laid concrete, and where sand and dust collect on the base it shall be removed carefully before the wearing surface is applied.

WEARING SURFACE.

27. Mixing. The wearing surface shall be mixed of one (1) part cement and not more than one and one-half (1½) parts fine aggregate, with sufficient water to produce a consistency which will not require tamping but which can be easily spread into position with a straight edge.

28. Depositing. The wearing surface shall be spread on the base immediately after mixing, and in no case shall more than fifty (50) minutes elapse between the time that the concrete for the base is mixed and the time the wearing course is floated.

The wearing surface of the pavement in a residence district shall be at least one and one-half (1½) inches thick, and in a business district at least two (2) inches thick. **29. Thickness.**

The wearing surface shall be finished with a wood float, and before it has completely hardened it shall be roughened by brushing with a stiff vegetable fiber brush or broom. **30. Finishing.**

The edges of all expansion joints shall be rounded to a radius of about one-half (½) inch. **31. Edges.**

Where coloring matter is required it shall be mixed dry with the sand and cement, which have been previously mixed dry, until the mixture is of a uniform color. The quantity and quality of the coloring shall be such as to not impair the strength of the wearing surface. **32. Color.**

PROTECTION.

When complete, the pavement shall be kept well sprinkled with water for a period of at least three days and shall not be thrown open to traffic until the engineer so directs.

Standard No. 6.

National Association of Cement Users.

PHILADELPHIA, PA.

STANDARD SPECIFICATIONS FOR PORTLAND CEMENT CURB AND GUTTER.

Adopted February, 1910.

MATERIALS.

1. Cement. The cement shall meet the requirements of the Standard Specifications for Portland Cement of the American Society for Testing Materials, and adopted by this Association (Standard No. 1).

2. Fine Aggregates. Fine aggregates shall consist of sand, crushed stone or gravel screenings, graded from fine to coarse, passing when dry a screen having one-quarter (¼) inch diameter holes, shall be preferably of siliceous materials, clean, coarse, free from loam, vegetable or other deleterious matter, and not more than three (3) per cent. shall pass a sieve having one hundred (100) meshes per linear inch.

Mortars composed of one (1) part Portland cement and three (3) parts fine aggregate by weight when made into briquettes shall show a tensile strength of at least seventy (70) per cent. of the strength of 1 : 3 mortar of the same consistency made with the same cement and standard Ottawa sand.

3. Coarse Aggregates. Coarse aggregates shall consist of inert materials graded in size, such as crushed stone or gravel, which are retained on a screen having one-quarter (¼) inch diameter holes, shall be clean, hard, durable and free from all deleterious matter. Aggregates containing soft, flat or elongated particles shall be excluded.

The maximum size of the coarse aggregates shall be such

that it will not separate from the mortar in laying and will not prevent the concrete from filling all parts of the forms. The size of the coarse aggregate shall be such as to pass a one and one-quarter (1¼) inch ring.

Natural deposits of sand and gravel usually being out of balance, shall be screened and remixed to agree with the proportions specified under Base. **4. Natural Mixed Aggregates**

Only clean, hard, suitable material shall be used, not exceeding four (4) inches in the largest dimension. **5. Sub-base.**

Water shall be clean, free from oil, acid, strong alkalies or vegetable matter. **6. Water.**

The expansion joint filler shall be a suitable elastic waterproof compound that will not become soft and run out in hot weather or hard and brittle and chip out in cold weather. **7. Expansion Joint Filler.**

SUB-GRADE.

When a sub-base is required the sub-grade shall be not less than twelve (12) inches below the finished surface of the gutter. **8. Depth Below Grade of Gutter.**

All soft or spongy places shall be removed and all depressions filled with suitable filling material, which shall be thoroughly compacted by flooding and tamping in layers not exceeding six (6) inches in thickness. **9. Depth of Layers.**

When a fill exceeding one (1) foot in thickness is required to bring the work to grade it shall be made in a manner satisfactory to the engineer. **10. Deep Fills.**

When required, a suitable drainage system shall be installed and connected with sewers or other drains indicated by the engineer. **11. Drainage.**

SUB-BASE.

A sub-base shall be provided if required by the engineer, composed of cinders or other suitable material hereinbefore specified, which shall be rammed thoroughly to a surface at least six (6) inches below the finished surface of the gutter. **12. Width; Thickness.**

While compacting the sub-base the material shall be kept thoroughly wet and shall be in that condition when the concrete is deposited. **13. Wet Material.**

FORMS.

14. **Material.** Forms shall be free from warp, and of sufficient strength to resist springing out of shape. All mortar and dirt shall be removed from forms that have been previously used.

15. **Setting.** The forms shall be well staked or otherwise held to the established line and grade, and their upper surface shall conform with finished surfaces of the curb and gutter respectively.

16. **Expansion Joint.** At least once in every one hundred and fifty (150) feet one-half (½) inch expansion joints shall be provided.

17. **Wetting.** All forms shall be thoroughly wetted before any material is deposited against them.

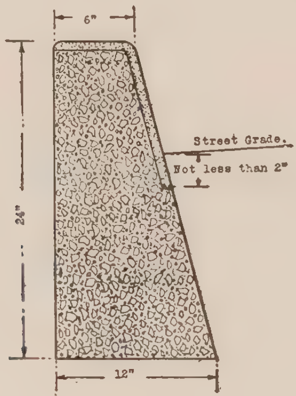

FIG. 1.

DIMENSIONS.

18. **Curb.** The section of the curb shall conform with that shown in Fig. 1.

The thickness at the base shall be not less than twelve (12) inches and the thickness at the top not less than six (6) inches, with a batter on the street side of one (1) to four (4).

19. **Curb and Gutter.** The sections of the combination curb and gutter shall conform with that shown in Fig. 2.

The depth of the back of the curb shall be not less than twelve (12) inches and the depth of the face not less than six (6) inches.

The breadth of the gutter shall not be less than sixteen (16) inches nor more than twenty-four (24) inches.

CONSTRUCTION.

The curb and gutter shall be divided into sections not less than five (5) nor more than eight (8) feet long, by some method which will insure the complete separation of the sections by a joint not less than one-eighth (1/8) nor more than one-quarter (1/4) of an inch wide. **20. Size of Section.**

The construction of the combination curb and gutter at street corners shall conform with that shown in Fig. 3. The radius of the curve shall be not less than six (6) feet. **21. Section at Street Corners.**

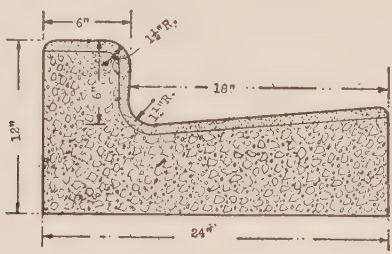

FIG. 2.

CONCRETE.

The concrete for the curb and gutter shall be so proportioned that the cement shall overfill the voids in the fine aggregate by at least five (5) per cent., and the mortar shall overfill the voids in the coarse aggregate by at least ten (10) per cent. The proportions shall not exceed one (1) part cement to eight (8) parts fine and coarse aggregates. When the voids are not determined, the concrete shall be composed of one (1) part cement, three (3) parts fine aggregate and five (5) parts coarse aggregate. **22. Proportions.**

The method of measuring the materials for the concrete, including water, shall be one which will insure separate uniform proportioning at all times. A bag of cement (94 pounds) shall be considered to have a volume of one (1) cubic foot. **23. Measuring.**

24. Mixing. The ingredients of the concrete shall be thoroughly mixed dry, sufficient water added to obtain the desired consistency, and the mixing continued until the materials are uniformly distributed and the mass is uniform in color and homogeneous.

25. Machine Mixing. When conditions will permit, a machine mixer of a type which insures the uniform proportioning of the materials throughout the mass shall be used.

26. Hand Mixing. When it is necessary to mix by hand, the mixing shall be on

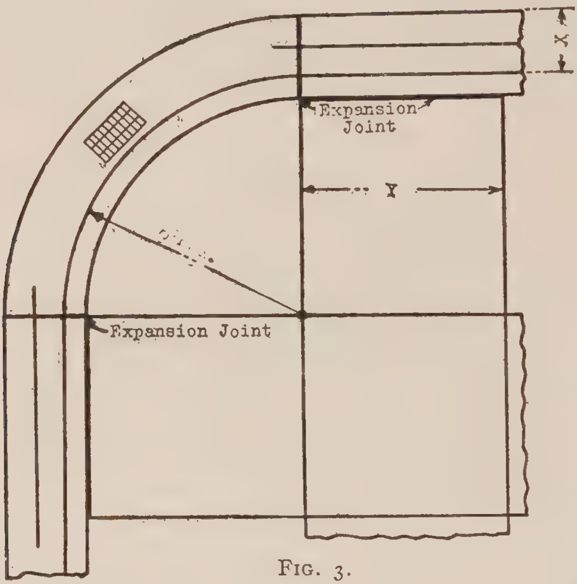

FIG. 3.

a water-tight platform and the materials shall be turned until they are homogeneous in appearance and color.

27. Consistency. The materials shall be mixed wet enough to produce a concrete of a consistency that will flush readily under light tamping and which can be handled without causing a separation of the coarse aggregate from the mortar.

28. Retempering. Retempering, that is, mixing with additional water, mortar or concrete that has partially hardened, will not be permitted.

29. Placing. A layer of concrete shall be deposited to the top of the gutter form and tamped, the width of the gutter, to a surface all points

of which shall be at least the thickness of the wearing surface below the finished surface of the gutter. The concrete placed for the curb shall be tamped and the remainder of the concrete placed and tamped to permit of the application of the required wearing surface to the face and top of the curb. After the addition of water the mixture shall be handled rapidly to the place of final deposit. Under no circumstances shall concrete be used that has partially hardened.

Concrete shall not be mixed or deposited when the temperature is below freezing unless special precautions are taken to avoid the use of materials containing frost and to protect the work against frost until thoroughly hardened.

Workmen shall not be permitted to walk on freshly laid concrete, and where sand or dust collects on the concrete it shall be carefully removed before the wearing surface is applied.

WEARING SURFACE.

The wearing surface shall be mixed of one (1) part cement and not more than two (2) parts fine aggregate, with sufficient water to produce a consistency which will not require tamping but which can be easily spread into position. The mortar for the wearing surface shall be mixed in a mortar box. **30. Mixing.**

The wearing surface shall be placed immediately after mixing, and in no case shall more than fifty (50) minutes elapse between the time the concrete is mixed and the time the wearing surface is placed. **31. Depositing.**

The wearing surface on the gutter and on the top and face of the curb shall be at least three-quarters (¾) of an inch thick. **32. Thickness.**

The surface and edges of the curb and gutter and joints between sections shall be finished in a workmanlike manner. **33. Marking.**

The edge of the curb on the street side and the intersection of the curb and gutter shall be rounded to a radius of about one and one-half (1½) inches; all other edges to have a radius of about one-half (½) inch. **34. Edges.**

When required, the surface shall be troweled smooth. The application of neat cement to the surface in order to hasten the hardening is prohibited. **35. Troweling.**

36. Color. When coloring matter is required it shall be mixed dry with the sand and cement which have been previously mixed dry, until the mixture is of a uniform color. The quantity and quality of the coloring shall be such as not to impair the strength of the wearing surface.

PROTECTION.

When completed, the curb and gutter shall be kept moist and protected from traffic for at least one (1) week.

TOPICAL DISCUSSION ON ROADWAYS, SIDEWALKS AND FLOORS.

Mr. Joseph F. Eilbacher.—I would like to ask as to the most practical method of surfacing roadways. There is quite a field for that sort of work in the east. We have been constructing sidewalks and paving alleys and floors, using the old method of finishing by troweling and jointing in the regular way, in blocks 6 ins. square, 8 ins. square, or parallel lines. In figuring a roadway, say 1 or 2 miles in length and 25 ft. wide, we cannot compete with brick or any other pavement at the present time. On all the roadways I have seen, such as the Motor Parkway on Long Island, for instance, they have put in an ordinary concrete so as to bring the finest aggregate to the surface and broomed them over. This does not seem to be a practical finish for a roadway. To adhere to the method of troweling and using an ordinary jointer, in the way that you would pave a small yard or private alleyway, would be prohibitive. **Mr. Eilbacher.**

Mr. C. W. Boynton.—In the practice it was probably thought necessary to cut the roads up into blocks, that is, little squares or rectangular shapes imitating granite block or brick pavement because the public were accustomed to pavements of these materials. If it is necessary, some footing can be provided for the horses but whether or not it is best to corrugate or cut the pavement into blocks as suggested, remains to be seen. Undoubtedly, roughening the surface of the pavement in some way is desirable, but I am not convinced that it is necessary to cut it up into blocks imitating other types of pavement. Possiby we could do it in some other way. I do not know that a brushed surface would make a road sufficiently rough for horse traffic; it might wear smooth rapidly. However, after becoming smooth it could not be more severely criticized than are asphalt and creosoted block pavements. **Mr. Boynton.**

I was recently advised by the Chief Engineer of the Borough of Brooklyn, of a piece of pavement laid in September, 1908, which

Mr. Boynton. was left rough, no effort made to smooth it. He states it is not slippery, has not cost a cent for repair in the 18 months it has been down and is as good to-day as when laid.

When considered from the view point of comparative cost and wearing quality with other types of pavement the most conservative must admit that concrete pavements are practicable. On the other hand the enthusiast must admit that concrete pavements have hardly passed the experimental stage so far as the best method of construction is concerned.

Mr. McCullough. Mr. Ernest McCullough.—I have laid small batches of concrete pavements in different places, and the great trouble that we found was the question of expansion joints. The custom now is to have expansion joints longitudinally with the road and across the road. The intervals being generally about 50 ft. As we all know, concrete is strong in the body but weak on the edges.

In Mason City, Iowa, they are making concrete roads and have been for two or three years, in which the expansion joints are only ⅜ to ¼ in. wide, filled with fine sand, and 25 ft. apart, running diagonally across the road at an angle of 45 deg., practically dividing the roadway into squares of 25 ft. Some tooling is done to give a little roughness for the horses, and it is then broomed. The road seems to be doing very nicely. The engineer who has charge of that work examined every roadway in this country of which he could find record. There is one thing in his specifications worthy of note, and that is, where he lays the road on clay, tile drains are placed on each side of the roadway, 18 ins. out from the curb, 18 ins. below the surface; then the trench is filled with hard cinders tamped in place. The cost is about $.08 per lin. ft. This pavement on the clay has passed through three winters and seems to be about as good as when laid. In wet weather there is considerable water running through those drains.

Mr. Birnie. Mr. A. C. Birnie.—I have had no experience in this line except on one very small piece laid under a railroad. We used gravel concrete, mixing in what would correspond to a 1 : 2 : 4 proportion without top dressing, and simply tamped it down and struck it off with a shovel. It was a slight grade, and has been in only about a year, but the parties for whom we did the

work have made no complaints whatever. It seems to stand up under work and apparently does not cause any slipping. Mr. Birnie.

We had an opportunity to figure on a concrete roadway, where the specifications called for a 1 : 3 : 5 bottom and a 1 : 2 top, the latter being about 1½ ins. thick. This is to be floated and then dusted with traprock screenings, that is, fine screenings, merely pressed into the surface. The idea of leaving the screenings on the top is simply to form a rough surface until such surface shall wear down and the stone mixed with the top begins to show. This road was designed principally for automobile traffic.

THE PRESIDENT.—I would like to ask whether any consideration has been given to the wearing or dusting of the top, to prevent the dust being worn off as in traffic by automobiles, which would tend to expose the aggregate and to decrease the wearability of the pavement. The President.

MR. BOYNTON.—The committee has not considered treatments to prevent dusting. A criticism of concrete pavements is that the automobile tires pull out particles from the surface as it begins to wear and in that way destroy the roadway. When we build only for automobiles we will probably build an entirely different kind of road than when we build for horse traffic. I do not know just how the question can be handled. Possibly we should have two sets of specifications, one for boulevards and another for business streets. Undoubtedly concrete pavements that will give the best satisfaction for heavy traffic will not be found entirely satisfactory for automobile traffic. It may be that after this matter is thoroughly discussed the Committee will be instructed to submit two specifications. Under these circumstances it will be necessary for the Committee to search for the form or method of construction which will give to the concrete maximum resistance to automobile traffic which is undoubtedly different from the impact wear of team traffic. We have studied roadways built under various conditions and have tried to draw some lesson from each case. From this experience we have written a specification. Mr. Boynton.

MR. HARRY FRANKLIN PORTER.—I have seen several concrete pavements, and while I am very prejudicial to them, I am Mr. Porter.

Mr. Porter. not altogether of the opinion, up to the present time, that cement forms a good wearing surface for roadways. I think something with more elasticity is necessary. I have been interested to note the increasing use of wood blocks with a concrete base. It is just as important in a wood block pavement, that the concrete base should be built properly and that there should be specifications covering it, as that an ordinary concrete pavement, with a concrete wearing surface, should have a proper base.

Mr. McCullough. Mr. McCullough.—In the matter of keeping down the dust, I believe the experiments and investigations made in different parts of the world on the rapid wearing out of macadam roads under automobile traffic have shown that the great trouble with the macadam roads is the lack of tensile strength in the macadam. It is caused by the wheels going around so rapidly, instead of sucking up the macadam from the roadway, as was the old idea, the stress is entirely a tangential stress. It is at right angles to the spokes of the wheels as they strike the roadway and has a tendency to tear the roadway to pieces. By using a binder that is very largely done away with. An automobile traveling not more than twelve miles per hour does very little damage to the roadway. It is the speeding that does the damage.

There have been a few instances where a concrete roadway has gone to pieces under automobile traffic, and in one particular case, automobiles went over it at 60 or 80 miles an hour. Some instantaneous photographs taken showed that where there was a depression in the roadway the automobile seemed to leave the surface, then strike on the roadway again and get another grip some 5, 6 or 10 ft. beyond where the depression existed. The roadway went to pieces under the fearful impact.

Automobiles going over roads do not seem to raise so much dust that we should take any particular precaution to guard against it. The only roadways on which much dust can be raised are roadways in which the material is rather loose and grinds down rapidly.

I understand Mr. L. W. Page, of the Bureau of Public Roads of the Agricultural Department, is making experiments with a new binder in the hope of making a concrete bitumen with cement instead of water to give a concrete wearing surface for macadam

roadways, instead of doing as in the past, experimented with bitumen and stone alone without any Portland cement in it. These experiments are for the purpose of obtaining a permanent surface for a road, and not so much with a view to cutting down the dust that may be raised by automobiles on the roadway. **Mr. McCullough.**

THE PRESIDENT.—The Chair would suggest the probable reason that concrete roads have not always been successful is not due so much to the ability of the material to suit the conditions to which it is put as the ability of those who are using it to do so properly. While concrete roads perhaps may not be the ideal pavement, nevertheless it does seem that we will have concrete roads that will be thoroughly satisfactory. I have seen concrete pavements on rather large streets in Europe which seemed to be serving perfectly well. A very careful study of the conditions of the laying of those pavements is the essential feature in the success of the road. Of course, they are comparatively new, and until we get some light on the durability of the various types of road proposed we cannot authoritatively speak as to how that can be done. **The President.**

The question raised by Mr. Porter, I think, is one worth discussing. There is no doubt that a road consists of a base and a wearing surface. Now whether or not that wearing surface must be also of concrete or should be of wood block or asphalt or some other material is a debatable question.

MR. BOYNTON.—I wish to say that concrete pavements are not a failure but a success. In some cases they have not been altogether satisfactory, but in most cases they have been a success. In forming our opinion of concrete pavements as a whole, we are apt to fail to recall that the very things which cause us to condemn concrete pavements are not uncommon to other types of pavements which are usually accepted as first-class. They may be slippery, but other pavements also are slippery. There is no pavement that is ideal, and if we fail to recommend concrete pavements until we get an ideal one we are not going to recommend it at all, for an ideal pavement will never be made no matter what materials are used. The very best is going to wear out and have some drawbacks. **Mr. Boynton.**

Creosoted block makes an excellent pavement in some re-

Mr. Boynton. spects; it is quiet and it has the advantage over concrete of being more or less elastic. But the wooden block pavement is extremely slippery. The creosoted block pavement is criticized because it is slippery, but it will not be condemned.

Concrete pavements may not stand automobile traffic as well as some others, but when one takes into account the cost together with the advantages and disadvantages it must be admitted that the concrete pavement is entitled to consideration by those dealing with the paving problem.

We should not wait until we can build an ideal pavement before we recommend concrete. Let us try to get together on something we can support, a specification that will give a good pavement, not necessarily an ideal one, but a pavement that is worthy of being called a pavement and one that will be worth more than it costs.

Mr. Snodgrass. Mr. A. E. Snodgrass.—I consider a rough surface preferable to the grooved marking on a smooth, finished surface. The failure of the paved street at Bellefontaine, Ohio, is partly due to the grooved marked surface. The tires of the heavy wagons pound the edges of the grooved marking and little chips of concrete continue to spall off each time the tire strikes the groove. I know of a warehouse floor divided into 12 ft. squares. The small iron wheels of the trucks passing across the grooves have broken off the little chips of concrete until there is now a space from 3 to 4 ins. hollowed out on each side of the groove. I do not think we should place very much importance on the smooth finished surface, but if possible get rid of the grooved markings.

Mr. Boynton. Mr. Boynton.—The pavement is cut into small blocks to provide a footing for horses, but as the wear on the pavement begins at the markings, possibly by some other treatment a pavement can be made sufficiently rough without grooving.

In drawing a specification it is desirable to avoid markings if a pavement without marking is practicable, if not, the number and position of the markings should be carefully considered. In our specifications we have not done that. We have simply told how to make the block and the approximate size. I wish it were possible to eliminate them entirely. With the markings eliminated the pavement will not be more slippery than asphalt or

creosoted block, and possibly if it is so important to get rid of the markings, we would be justified in sacrificing something in roughness in getting a pavement that will wear less rapidly. Mr. Boynton.

MR. MCCULLOUGH.—A large part of that cutting in finished floors, from my own experience, comes from too rich a mixture in the top. I have experimented with a 1 : 1, 1 : 2 and 1 : 3 mix for the top coat, and the richer you get your mix the more brittle it is and the more apt to go to pieces on impact. I have noticed some sidewalks used by children for roller skating, one sidewalk in particular about one-half a block long. The contractor had used a much leaner mix, according to the inspector, than the sidewalk adjoining it. The one in which 1 : 3 had been used instead of 1 : 1 appeared to be much better under roller skating than the richer mixture. I believe the greater number of failures in concrete roadways reported, have been where the contractor has tried to do a good job and put in a richer mixture than he should. We have had the most success with a 1 : 5 mixture with a top of 1 : 3, and it is put on and rolled with a hand roller before setting. Mr. McCullough.

MR. LEONARD C. WASON.—Where a granolithic surface is used as the wearing surface for floors of buildings and sidewalks, more or less chipping at joints can be observed. For instance, in a stable built a good many years ago, and which was observed for a number of years, it was found that joints made with the ordinary style of sidewalk jointer were chipping badly. When the chipping reached its limit the angle of the side of joint was about 45 deg. with the top, and the bottom was rounded. Some grooving jointers of about this shape were made and used in stable work. One in particular, was a stable used for very heavy horses, whose shoes are kept pretty well sharpened in winter. They did not seem to damage the groove at all, and it stood up beautifully for a number of years. Mr. Wason.

The chief wear to joints seemed to be from the tires of wheels in mills which use granolithic surfaces. In one instance, a laundry had trucks with 4 in. wheels, loaded with wet clothes weighing about one-half a ton. They always went in the same passageway, a narrow one, turning and stopping at exactly the same place before a centrifugal wringing machine, thus twisting and wearing a hole. I induced the manager to use a little larger wheel with

Mr. Wason. a crown face, a good deal like the crown face of pullies, and the wear was very materially reduced.

When a floor is to be subjected to the abrasion of wheels it is best to make no joints at all; simply stop a day's work with a perfectly square shoulder and begin another one right against it, without using jointers. A terrazzo floor has no joints and generally serves as well as a solid floor.

Inside of a building the question of dust is very important. Inquiries have been made of manufacturers that have used both wood and granolithic floors and over two hundred replies received, which have been tabulated. The consensus of opinion was that granolithic was much superior to wood, which is practically the other type of mill floor in use. The chief objection seems to be the question of dust, and it seems to me that with a cement floor, this is due to the absence of joints and the hardness of the surface, so that dust which does not come from the floor itself, but settles upon it, is often mistaken for dusting of the floor surface. In the case of wooden floors shrinkage makes joints between the boards which collect the surface dust and which at regular intervals is swept out in the ordinary process of cleaning, so that the floor is apparently very much cleaner and freer from dust.

To get a hard wearing surface which is as free from dusting as possible it is necessary to select a hard stone, and use it with very little sand. Then in a short time the cement troweled surface wears off, and produces a pavement which looks very much like terrazzo, the hard stone taking all future wear. In street paving the thing to do is to select a very hard and durable stone for the wearing surface and use as much stone as possible with just enough mortar for a binder to hold it in place. Then you are relying on the wearing power of the stone rather than the mortar.

Mr. Kleiderer. MR. E. L. KLEIDERER.—In speaking of stone I should judge from my experience that gravel would be better because the dust from the limestone will make dust on the floor, whereas a gravel will not wear off as quickly. We placed about 12,000 ft. of flooring in a factory two years ago, using 4 ins. of concrete of a 1:2:5 gravel mixture and a top 1 in. thick of 1:1:1 torpedo gravel mixture. They have large trucks about 4 ft. by 9 ft. to carry

tobacco from the wagons of farmers over this floor, which is just as good now as at first. The torpedo gravel holds better than limestone. Our limestone wears very quickly and gets dusty. **Mr. Kleiderer.**

Mr. Wason.—I did not mention any particular kind of stone, only a stone suitable for the purpose. Throughout New England we have a hard traprock which is very much superior in resistance to abrasion than limestone. Gravel, which is also plentiful, gives good results. In different localities the quality or kind of stone would vary somewhat. Gravel which consists largely of very hard pieces of quartz or granite is preferable to limestone. The chief difference in the beginning of the wear would be that with gravel there would be just the top round to take the wear, whereas with broken stone which is tamped gives flatter surfaces, thus there would be larger surfaces to receive the first wear. It takes some time for a gravel surface to wear down to get a stone surface to resist the wear; whereas, a broken stone exposes considerable surface from the beginning. **Mr. Wason.**

Mr. Eilbacher.—We have had quite some experience with factory floors, and the only trouble we had was when the top dressing was made with Long Island grit, which is produced by the action of the surf against the shores of Long Island. This was mixed in the proportion of 1:2. The only trouble occurred where factory trucks for transporting material from one end of the factory to the other caused chipping of the joints. To overcome this difficulty we used a jointer with a larger angle, so that instead of having the sides of the groove perpendicular, they were at an angle of about 30 or 45 degrees. This makes quite a large looking joint on the top, but overcomes the right angle on the edge of the block, and after that we had very little difficulty. **Mr. Eilbacher.**

Mr. Porter.—It has been my experience that a large part of the dusting of ordinary concrete surfaces is due to one of two practices. The one is the practice of using a rather wet mixture for the top dressing, in order that it should spread easily, which in itself is not undesirable, and to dry up the surplus moisture with dry cement in order to facilitate troweling. This gives a surface rich in cement, and very loosely knit to the body, so that with a very little attrition it comes off and forms a dust. **Mr. Porter.**

The other is the use of insufficient water to properly cure

35

Mr. Porter. the surface. Of course, a cement surface after it has been well troweled, apparently is the essence of smoothness, but as a matter of fact, it is not smooth at all. If you were to examine with a magnifying glass, you would find it replete with minute pores. Moisture evaporates very rapidly from these pores, leaving innumerable little nodules exposed to wear. If, after the surface is troweled, it were covered with wet sand for a few days, I think a great deal of this trouble would be obviated.

Mr. Lindau. MR. ALFRED E. LINDAU.—I am interested in Mr. McCullough's remarks regarding the cracking of concrete surfaces, particularly of rich mixtures. This agrees with my own experience. Further where the mortar of a richer mixture is put on top of concrete of a leaner mixture, the difference of density or coefficient of expansion may cause surface cracks and separation of the finish from the body of the concrete.

Mr. Boynton. MR. BOYNTON.—I think Mr. Porter is correct in his statement that the dusting of floors is largely due to the way the floor is laid. I know that here in Chicago every little while we hear of a concrete floor being unsatisfactory to the tenants because of dust. Mr. Lindau intimated that floors are laid according to the convenience of the people that lay them, which is apparently the case. I believe Mr. Porter is correct in his statement that the drying out of floors is largely responsible for dusting.

The Committee will not make recommendations this year on concrete floors simply because the question of preventing dusting is unsettled.

I would like to ask Mr. Wason in reference to the joints he referred to, if he made any effort to unite work laid at different times or were cracks allowed to occur at these points? It seems to me the cracks there would be practically as bad as a joint; they would start to wear some time, though possibly not quite so soon as would a grooved joint.

Mr. Wason. MR. WASON.—Floors are sometimes put down at a single operation without joints, as large as 30 ft. square; that is, 900 ft. for a day's work; and after several years there have been no cracks in them. This was put down as a portion of a big mill. Simply stop with as square a joint as possible against a piece of wood. The next day the concrete was packed against that which

had set, without any effort to bond the work together or any special effort to keep them separate. Of course there is a shrinkage crack, but that is very much smaller in size than a joint, and, therefore, a wheel bridges it for a very much longer period without wear. A line jointer cuts a groove ¼ to ⅜ ins. wide as a rule, and it leaves an edge for a wheel to abrade very much quicker than a crack which would shrink open, perhaps, only 1/32 in. **Mr. Wason.**

There is one point not touched upon this afternoon and that is strong curbs. I would like to ask if there has been much trouble with curbs being chipped and broken by wheels of wagons grinding against them, moving either parallel to, or backing up at right angles, and what radius should be used to avoid chipping. Do acids or alkalies which are found in the ground or dropped upon the surface cause damage to cement.

Mr. Boynton.—Mr. Wason says that a slight crack will occur, and I think we all agree that it will become a weak point and will wear much faster than the balance of the floor. We want to make the floors just as good as can be made for the money, and if any one can suggest how a floor may be made a monolith, economically, I am sure the suggestion will receive consideration. It does seem that there might possibly be some way to avoid even the crack that occurs between concrete laid at different times. **Mr. Boynton.**

As to the proper radius for the upper edge of the street side of curbs I can only say that the Committee has considered this point quite thoroughly and is convinced that a 1½ in. radius will protect the curb quite perfectly. With such a radius I do not believe that the curb can be greatly damaged by the wheels of vehicles coming back against it.

The heaving of a curb or curb and gutter I think is very much like the heaving of sidewalks. It is hard to handle the matter to the entire satisfaction of all. Sidewalk construction has never come before the Association for discussion that cinder fills and sub-base have not consumed a large portion of our time. The more I hear it discussed the more I am inclined to believe that we sometimes waste cinders; at the same time there is no doubt in my mind but that a cement walk would be a failure on some

Mr. Boynton. soils if a sub-base were not used. I believe the same will hold good in reference to curbs.

The effect of acids and alkalies on the surface of concrete I do not believe we need to consider. Under ordinary conditions the amount of acids or alkalies coming into contact with pavements and gutters will be so small that their effect can be ignored.

Around ice cream plants and such places we find that salt affects the floors. I have also seen sidewalks roughened by the use of an excessive amount of salt in keeping them clean of ice and snow. The effect of salt may be overcome somewhat by making an effort to get a dense surface. Dense concrete resists alkali and acids quite effectually, some oils also effect a poor, porous concrete; whereas concrete made impervious will stand the action of oils indefinitely.

Mr. Schuyler. Mr. Schuyler.—I would like to ask Mr. Boynton what he means by density, whether he means a larger quantity of fine, hard sand than using so much coarse sand or gravel.

Mr. Boynton. Mr. Boynton.—I do not mean either, but refer to a concrete mass or surface which is compact, which contains a minimum amount of air spaces, concrete that is impervious. The aggregates should be carefully studied, selected and proportioned to give the greatest density. A given mixture with one set of materials will give an entirely different concrete than the same mixture with other materials.

Mr. Porter. Mr. Porter.—I would like to ask Mr. Boynton if he made any investigation, or found any data which was of value in regard to the effect of temperature on the setting of cement. Now below 40 deg. temperature, the compounds are different than those formed above that temperature. They are less stable, being more loosely crystallized, and, therefore, concrete laid under these conditions would be much less durable, hence more prone to dusting.

Mr. Boynton. Mr. Boynton.—One can study the results of tests made on the effect of temperatures on concrete and arrive at most any conclusion. I mean that the results of no two investigators agree. I am conducting tests on the effect of temperatures on concrete and though the tests are not completed it is very evident that the rate at which concrete gains strength in a temperature below the freezing point is extremely slow. This, of course, is just what

one would expect, yet we often find builders who seem very much surprised when the results obtained in winter work are not as satisfactory as those obtained in warm weather. **Mr. Boynton.**

MR. PORTER.—The compound formed in the final hardening of Portland cement, has, in my opinion, a great deal to do with the behavior of cement surfaces. Investigations recently conducted appear to indicate that final compound is a resolution back to the carbonate form; and if so, the surcharge of the air over a fresh surface with carbonic acid, hastening this resolution back into carbonate, would induce dusting. Attesting the effect of temperature, an experience I had in Toronto brought me to the conclusion that it was foolish to try to concrete unless a temperature above 50 degrees could be maintained. A floor put in in February, using salamanders and carefully covering the work, was not so hard by the first of May as a floor placed in the warm days during the first of April; so there was nothing gained by essaying to concrete in winter. **Mr. Porter.**

THE PRESIDENT.—The Chair would suggest that in a good many cases dusting is due to the formation of laitance. A floor laid with very wet concrete is favorable to the formation of laitance, and with the drying out of the concrete the laitance begins to dust and will continue to do so for quite a long time. I am not at all in accord with Mr. Porter's theory on the formation of carbonate. I do not believe there is any basis for such a statement. **The President.**

MR. SCHUYLER.—I would like to ask whether frost deteriorates the cement, or after the frost has gone will the cement do its work and show a fairly good job, the same as though there had been no frost in it? **Mr. Schuyler.**

THE PRESIDENT.—The action of frost is to suspend the hardening. If, during the period in which this takes place, there is an alternation of freezing and thawing the result is the breaking down of the partially hardened mass, and if it is repeated a sufficient length of time, you will destroy the strength of the mass. The mere freezing of concrete simply suspends the hardening and in a freezing temperature if the process of hardening has proceeded far enough, the generation of heat will be sufficient to permit the hardening to go on even in a freezing temperature. **The President.**

The President. It is the repeated freezing and thawing of concrete partially set that is destructive.

Mr. Boynton. MR. BOYNTON.—I believe a floor can be laid so as to avoid any sign of a joint or crack between concrete placed at different times. I have never done it but assume this from the fact that here in Chicago and elsewhere one sees patched sidewalks where the bond is perfect.

Mr. Chandler. MR. CHANDLER.—My experience in that line is that I have had some success and some failures. I usually take neat cement and plaster that joint thoroughly, troweling the facing into the old concrete. Then the new is laid and carefully troweled while it is setting and I have had very little trouble that way. If the floor is thick enough the old concrete is allowed to project under the new, forming a shoulder. Thereby a better adherence to the old concrete is obtained.

Mr. Eilbacher. MR. EILBACHER.—The only trouble I have had with dusting came usually from having the surface troweled up and left too wet. For instance, the men would put in a top dressing late in the afternoon, and being anxious to get away from the work, they would not give it the proper manipulation after the initial set. Another instance is when not being able to get the proper coarse material to put in with the top dressing, we would be compelled to use finer sand or even stone dust. I have known 9 cases out of 10 where it would go wrong, so that we did not get the proper binding between the cement and the dust. I do believe that if the surface is properly mixed with coarse material, of a hard nature, and the curbing properly taken care of, dust can be avoided.

The President. THE PRESIDENT.—I think there are a good many items that enter into the cause of dusting, and it does not necessarily follow that the workmanship is solely responsible. For instance, the use of fine sand or of soft stone screenings having a great deal of flour, are both causes of a tendency to dust, for the reason that the flour and fine sand do not produce the rapid hardening surface which is essential. Wear will come on it before it has a chance to properly harden. I also think dust can be produced by too much troweling of the surface.

In the matter of joints, I think it is a fact that if the pave-

ment is laid at a time of the year when the temperature is low, then during the rise in temperature, they can expand without serious production of cracks. On the other hand, if you lay them when they are expanded, then in the colder weather they will shrink and crack. **The President.**

Mr. Snodgrass.—I would like to ask as to experience with the expansion joint. Nearly all of us have seen curbs that have been either broken or pushed out of line 2 or 3 ins. by expansion. It is often specified that expansion joints shall be filled with something. I would like to ask if it is not a fact that the curb being pushed out of line is caused by the joints being filled thus allowing no room for expansion of the concrete. **Mr. Snodgrass.**

Mr. McCullough.—The filling of the expansion joint is an absolute necessity. If the expansion joint is not filled with some plastic material then it will ultimately fill up with dust and sand and soon there is no expansion joint in the material, in which case it will be unyielding. The expansion joint should be filled with some compound of pitch or asphalt, so whenever the expansion takes place this plastic material can be forced up out of the joints. Of course, this reduces the effective width of the expansion joint. The only remedy is to put the joints closer together and make them narrow. But if not filled they will fill up with dust and the effect of the expansion joint will be lost. **Mr. McCullough.**

Mr. Boynton.—A good many sidewalk specifications require that the expansion joint be filled with sand. It might as well not be filled at all as be filled with sand. The effect of filling with plastic material is clearly shown by studying the curbing and paving at Gary, Ind. As most of you have read, the principal streets of Gary are paved with concrete. Expansion joints were left about every 50 ft. and filled with plastic material, a pitch or asphalt preparation. When hot weather comes the material is forced up as the expansion takes place and everything passing over the joints carries part of it away. Not only this but the joints look badly as the filler is smeared for several inches both sides of the joint. When it becomes cold and the pavement contracts the filler is gone. I do not know just how we are going to take care of this problem for a plastic material is very easily forced out by expansion and is soon lost. After a season or **Mr. Boynton.**

Mr. Boynton. two the expansion joint will become practically ineffective, because it fills with material that is no longer plastic. In sidewalks I believe it is better to leave the joints open than it is to try to fill them with sand or to fill them with plastic material. I believe that the expansion joints in sidewalks and between the sidewalks and curb, should be left open and so far as possible kept open. It should be the business of a city employee to see that the joints are cleaned out once a year.

As to street pavements, it remains to be seen just what can be done about expansion joints.

Mr. McCullough. MR. McCULLOUGH.—The trouble with the joints in Texas was that they were not close enough together and were entirely too large. If they had been closer together they could have been much smaller.

Fifteen or twenty years ago there used to be a clause in every sidewalk specification requiring the sidewalk to be laid in alternate blocks and three thicknesses of tar building paper placed against the end of each block and cut off when the concrete set. That gave an expansion joint against every block. There was no filling in and the small joints between the pieces of paper helped take up some of the movement. If you are not going to use some plastic material and are going to leave the joint open, then of course the joint should be very close and the block should be very small.

Mr. Boynton. MR. BOYNTON.—It is a fact that when sidewalks were laid in alternate blocks very little trouble occurred from expansion. I believe that in building sidewalks in this manner sufficient space is provided between the slabs to take care of the expansion. The reason so much trouble is had with expansion to-day is due to the fact that great stretches of walk are laid as a monolith. If the old practice of laying alternate blocks was followed I am of the opinion that trouble with expansion would be over.

Mr. Chandler. MR. CHANDLER.—My experience is if you leave the joints perfectly open you will have trouble. My experience with a sand joint has been that it is good. The interlocking of the two blocks will keep them from raising above each other, and will also allow for expansion and contraction.

I built a large driveway this year and used pitch expansion

joints every 40 feet. My experience is that if the joint is left open you will have trouble in the raising and lowering of the blocks. Mr. Chandler.

MR. W. M. NEWTON.—I have found it most satisfactory, when the end of a pavement terminates at a curb, to place the expansion joint between the curb and pavement underneath, that is, allow the pavement to lap over and face with the curb instead of abutting. Any expansion of sufficient force to break the curb off would merely push the end of pavement out of line with face of curb where the pavement laps over, causing no damage to the work. The projection, if sufficient to be unsightly, can be chipped off. Mr. Newton.

MR. SNODGRASS.—I would like to ask how far apart the expansion joints should be spaced. I have laid several miles of sidewalk in the southern states but have been unable to get in the expansion joint to the entire satisfaction of many of the engineers. The City of Lake Charles, La., specifies a ½-in. expansion joint spaced 30 ft. apart. An engineer in a city nearby forbids the expansion joint in their sidewalk construction and points to stretches of walk that have been down for 10 years and which show no defect whatever. Mr. Snodgrass.

MR. KLEIDERER.—In Kentucky we put our joints very close, fill them with sand and do not have any trouble, although it gets pretty hot down there. We make our joints about ½ in. every 20 ft. Mr. Kleiderer.

MR. EILBACHER.—In our experience in sidewalks where they were only narrow widths, from 4 to 6 ft., say a block in length, 400, 500 or 600 ft., there is certainly a great amount of expansion, there is no question about it. Where that particular walk joins a curb running around the corner we would in all instances stop the curb on the under side of the slab and have this lip over the top of the curb. So what expansion or contraction takes place will cause the slab to ride over the top of the curb itself. That was simply brought about by experience. We found that by putting on the curb first, starting on the corner and working from one end of the block to the other, the curb would either be pushed out or a crack form on the under side of the slab. In all cases of a narrow walk we do that, and in a good many instances Mr. Eilbacher.

Mr. Eilbacher. we find it is more practical even in walks from building to curb. Instead of finishing the curb right up to the top surface, we build it 6 or 8 ins. wide to within the thickness required for sidewalk slab, leaving the joint in order to stop the curb at the under side of the slab and finish the edge of the sidewalk over the top of this curb. Whatever expansion takes place from the building to the curb will ride over, leaving a horizontal joint. It is just the same as a sidewalk joint would be on the top surface of the walk, making a horizontal joint along the street walk. In all cases where there is a curb used we give it a good batter, not make it plumb or vertical, so as to obviate the scraping of wheels at the top edge of the curb.

Mr. Genthner. MR. WILLIAM J. GENTHNER.—I would like to ask in regard to expansion, whether it generally takes place the same year the walk is laid or the following season.

Mr. Eilbacher. MR. EILBACHER.—In my experience I find that expansion takes place as soon as the temperature changes.

Mr. McCullough. MR. MCCULLOUGH.—It has been my experience that the temperature changes will be noticed in the sidewalk each year. I put in a stretch of sidewalk 4 ft. wide, 6 ins. thick and 700 ft. long without any joints across it at all. It was put in a parkway and the grass came up to the surface on each side of it. There was nothing at either end to interfere with any movement that might be caused by expansion and contraction. We thought for three years that it was an absolute success and no expansion joints were needed; but at the end of three years that sidewalk had checked off pretty regularly in 25 ft. lengths. In the summer time the thermometer used to indicate in the shade sometimes from 105 to 110 deg. The minimum temperature in the winter would run from 1 to 3 below zero. So I concluded that sidewalks of that kind with expansion joints every 25 ft. apart and extremely narrow blocks joined would do. If the sidewalks are butted up against curbs or built under the usual conditions of city sidewalks, 8 to 10 ft. would be a proper distance, and the joints should be as narrow as possible. In laying walks after that I put in alternate blocks, and painted the edges of the block with heavy bitumen, giving probably 1/8 or 3/16 ins. of a coating of bitumen on the ends of the blocks. The joints hardly showed

and still there was plenty of room for expansion or contraction and no danger of any dust or dirt falling in between to cause any great difficulty in case of expansion. I found also that there was quite a difference in the size of the expansion joints, depending on the temperature of the day the work was done. If the work is done early in the spring or late fall, when the temperature would be say somewhere between 45 and 60 deg., there is hardly any rule that can be followed for the expansion joints. If the work is done in the summer then make the expansion joints very small and tight and they will open up considerably as the weather gets colder. If the work is done in the winter then pretty wide expansion joints have to be used and sufficient bitumen to allow of the necessary movement. **Mr. McCullough.**

MR. LINDAU.—I should like to ask Mr. McCullough how he accounts for a sidewalk standing up two years and falling the third. If there are any physical reasons that he could give why it should not stand up indefinitely after standing two years. **Mr. Lindau.**

MR. McCULLOUGH.—I could not see it myself. The idea was this: there was some expansion and contraction taking place, undoubtedly. I think that the sidewalk contracted and expanded in a body rather than in one direction, and the temperature of the surrounding soil in which it was imbedded had a great deal to do with the fact that there was no change apparent on the surface. It was largely owing to the fact that this sidewalk was imbedded in the top soil that led me to make the experiment, and I was astonished myself the third year, when the cracks did appear in the fall. I cannot explain it except that perhaps the body of the sidewalk had been expanding and contracting for a long time within the limits of its strength, until a certain amount of cohesion was destroyed and then cracks appeared. **Mr. McCullough.**

MR. KLEIDERER.—Alongside of that sidewalk during those two years, were there any trees? I thought maybe if there were and they were trimmed up, then the pavement was exposd to the hot sun, that maybe would cause cracks. **Mr. Kleiderer.**

MR. McCULLOUGH.—There were small trees about 20 ft. from the walk. They had not grown large enough to throw any shade on the walk. It was exposed to all the heat that could come. **Mr. McCullough**

Mr. Genthner. MR. GENTHNER.—I have noted in several walks laid with open joints that each year these joints become larger. I can attribute no other cause than the freezing of water in the joints, the expansion of which must move the blocks.

Mr. Schuyler. MR. SCHUYLER.—I would like to ask whether this contraction and expansion is more noticeable in a northern climate, where there is a great deal more frost, than it is in some southern climates where they have little or none?

Mr. McCullough. MR. MCCULLOUGH.—I sent out some four hundred letters a few years ago making that very inquiry and could not find that there was any difference at all.

REPORT OF THE COMMITTEE

ON

SPECIFICATIONS FOR CEMENT PRODUCTS.

In preparing specifications for certain cement products, two methods have been employed. One method is to word the specification so as to leave to the discretion of the manufacturer the methods of mixing, molding and curing the cement product and to specify the character of the finished product, giving various tests and requirements to which it must conform, also giving directions as to how the finished product shall be incorporated into the work for which it is intended. The second method is to describe the processes of manufacture and cover some of the points in the first method, but the number of tests to which the finished product is subjected is generally not so extensive.

With products of this kind, which are usually made at a factory, it is difficult to prepare a specification describing the manufacture of the products which will be sufficiently general to cover all methods of manufacture. The Association should, therefore, consider which method should be used in specifications of this kind.

The Committee has prepared a Specification for Plain Concrete Drain Tile and one for Architectural Concrete Blocks. In preparing these specifications it has been endeavored to conform, as far as possible, to the standard specifications already adopted by this Association, and which follow the second method mentioned above.

In considering these specifications it is thought desirable to call attention to certain points and to mention certain suggestions that have been made to the Committee since the specifications were printed.

PLAIN CONCRETE DRAIN TILE.

Materials. First, that for the production of a strong impermeable tile it might be well to emphasize more fully the value

of coarse sand, though it would probably be impracticable to definitely specify the coarseness of the various sieves. The following clause has been suggested to replace that under "Fine Aggregate."

The fine aggregate shall consist of sand, crushed stone or gravel screenings, preferably of a siliceous nature and passing when dry a sieve having four meshes per lineal inch. It shall be clean, free from vegetable loam, or other deleterious matter and shall be well graded from fine to coarse, with the coarse particles predominating, the coarseness being such that at least 60 per cent. shall be held on a sieve having thirty meshes per lineal inch, and that not more than 5 per cent. in the case of natural sand, nor more than 10 per cent. in the case of crushed stone or gravel screenings shall pass a sieve having one hundred meshes per lineal inch.

Second, that in the clause relating to "Coarse Aggregate," the words "retained on a sieve having four meshes per lineal inch" be substituted for the words "retained on a screen having ¼ in. diameter holes."

Third, that sea water salts should be excluded, and that the clause as given for water does not do this.

Mixing. It has been suggested that the last clause in reference to mechanical proportioning might exclude certain mixers which have given satisfactory results, and should be changed to read as follows:

All concrete shall be prepared and mixed in quantities requiring one or more full bags of cement. Methods of measurement of the proportions of the various ingredients, including the water, shall be used, which will secure separate uniform measurements at all times.

There seems to be some difference of opinion as to the mixture that should be used in making tile. It will also be noted that a difference is made in the specifications in the proportions required for hand and machine made tile. Machine made tile are necessarily composed of a mixture which is rather dry and for hand made tile it is required that the concrete be of a consistency which will be forced into every part of the form by jarring or tapping. With this consistency it is considered that a 1 : 2½ : 5 mixture will give equally as good results as a 1:2:4 mixture of the consistency required in the manufacture of tile by machine.

It may be desirable to slightly change the first paragraph under "Mixing" to read as follows: "The ingredients of concrete shall be thoroughly mixed in a practically dry state, sufficient water added, etc." We believe this change would be advisable as the aggregates are not always obtainable in an absolutely dry state.

Curing. In reference to curing there is some question as to the time required. This also applies to the temperature of the atmosphere in steam curing.

Dimensions. Some specifications for concrete pipe allow a certain percentage of variation in dimensions, and require tests for strength and imperviousness. The minimum thickness of the wall is sometimes less than that given in these specifications.

ARCHITECTURAL CONCRETE BLOCKS.

The specification for Architectural Concrete Stone was changed in printing to read: "Architectural Concrete Blocks." The Committee believes that Architectural Concrete Stone is the best heading for this specification, but it would be proper for the Convention to consider this point.

The specifications submitted cover stone made by the tamped process and not stone which is poured.

The suggestions made in reference to the specification for Plain Concrete Drain Tile in so far as materials and proportions are concerned would apply to this specification as well.

Facing. In reference to the clause Facing, it might be well to change the first paragraph to read:

> The facing shall consist of one part Portland cement and two parts fine aggregate (1:2) which shall be not less than 1 in. in thickness from any point on the exposed surface. It shall be thoroughly tamped into place in the mold and the backing immediately deposited. The surface between the facing and the backing shall be roughened to improve the bond.

Consistency. Under this heading it has been suggested to specify something concerning the waterproof qualities of the stone. The absorption might be limited to say 10 per cent.

Reinforcement. The question of reinforcement should be considered. This is required not only for shrinkage, but also

to prevent breakage in handling the stone, or in case of rough usage after being erected. It has been suggested that shrinkage does not properly describe this steel, and it would be better to call it reinforcing steel.

It is also suggested that the hooping as specified is so close that it will interfere with the tamping. It also might be better to place the reinforcement ½ in. back of the facing instead of the way it is specified.

Curing. The same points mentioned in reference to curing in the case of drain tile will apply here.

Laying. It is suggested that cement mortar is more likely to stain the stone than lime mortar, and that the latter would be strong enough where great weights are not to be carried.

CEMENT HOLLOW BUILDING BLOCKS.

The Committee would suggest that the present specifications for Cement Hollow Blocks be discussed as to their practicability in past experience. It has been suggested that it would be advisable to adopt a standard thickness of joint and that for good appearance this should be made thin. The minimum thickness practicable at the present time is about 5/16 in. It is suggested that members who have had experience in laying blocks give their views on these points.

ADDITIONAL SPECIFICATIONS.

The Committee would like suggestions as to the cement products for which it is thought desirable to prepare specifications, and also that those members who have had experience with these products communicate with the Committee, so that in preparing specifications advantage can be taken of their experience.

W. P. ANDERSON, *Chairman,*
PETER GILLESPIE,
J. Y. JEWETT,
H. C. TURNER,
P. H. WILSON.

NOTE:—The specifications for Architectural Concrete Blocks and Plain Concrete Drain Tile appear in the following pages in their proposed form. The convention referred the specifications back to the committee with instructions to report at the next convention.—ED.

National Association of Cement Users.

PHILADELPHIA, PA.

PROPOSED STANDARD SPECIFICATIONS FOR ARCHITECTURAL CONCRETE BLOCKS.

MATERIALS.

Cement. The cement shall meet the requirements of the Standard Specifications for Portland Cement of the American Society for Testing Materials, and adopted by this Association (Standard No. 1). **1. Materials.**

Fine Aggregate shall consist of sand, crushed stone, or gravel screenings, graded from fine to coarse, passing when dry a screen having ¼-in. diameter holes, shall be preferably of silicious materials, clean, coarse, free from vegetable loam or other deleterious matter, and not more than 6 per cent. shall pass a sieve having 100 meshes per linear inch.

Mortars composed of one part Portland cement and three parts fine aggregate by weight when made into briquets shall show a tensile strength of at least 70 per cent. of the strength of 1 : 3 mortar of the same consistency made with the same cement and standard Ottawa sand.

Coarse Aggregate shall consist of inert material, graded in size, such as crushed stone or gravel, which is retained on a screen having ¼-in. diameter holes and will pass a 1¼-in. ring, shall be clean, hard, durable, and free from all deleterious matter. Aggregates containing soft, flat or elongated particles, shall be excluded.

Water shall be clean, free from oil, acid, strong alkalies or vegetable matter.

PROPORTIONS.

2. Proportions. A bag of Portland cement weighing 94 pounds shall be considered as one (1) cubic foot. All concrete shall be prepared and mixed in quantities requiring one or more full bags of cement; the use of any device for mechanically proportioning the materials is prohibited.

Backing. The backing of all block shall be made of one part Portland cement, two parts fine aggregate and four parts coarse aggregate (1:2:4).

Facing. The facing shall consist of one part Portland cement, two parts fine aggregate (1:2), and shall be one (1) inch in thickness. It shall be thoroughly tamped into place in the mold and the backing immediately deposited. In order to prevent checks and hair cracks troweling will not be permitted.

Only cement of the same color shall be used. Cements causing efflorescence shall not be used.

The facing material shall not be allowed to become lumpy and shall be screened if necessary.

Where color is required, only mineral colors shall be used.

MIXING.

3 Mixing. The ingredients of concrete shall be thoroughly mixed dry, sufficient water added to obtain the desired consistency, and the mixing shall continue until the cement is uniformly distributed and the mass is uniform in color and homogeneous.

a. Measuring Proportions. Methods of measurement of the proportions of the various ingredients, including the water, shall be used which will secure separate uniform measurements at all times.

b. Machine Mixing. When the conditions will permit, a machine mixer of a type which insures the proper mixing of the materials throughout the mass shall be used.

c. Hand Mixing. When it is necessary to mix by hand, the mixing shall be on a water-tight platform and the materials shall be turned until they are homogeneous in appearance and color.

d. Consistency. The materials shall be mixed so as to pro-

vide sufficient water to insure a proper bonding and a dense concrete free from voids.

e. Retempering. Retempering mortar or concrete, *i. e.*, remixing with water after it has partially set, shall not be permitted.

REINFORCEMENT.

Bending. Sufficient metal reinforcement shall be provided to carry all stresses produced by the loads to which the blocks will be subjected. **4. Reinforcement.**

Shrinkage. No shrinkage reinforcement is required in blocks whose least dimension is more than one-third ($^1/_3$) of the length, such length being less than three (3) feet.

All blocks less than four (4) inches square shall have in the center at least one bar equal to ½ of 1 per cent. of the cross section.

All blocks over four (4) inches square shall have at least four ¼-inch square bars, with mechanical grip, extending throughout the length of the stone, one bar to be placed in each corner.

All blocks of over fifty (50) square inches in cross section shall have reinforcement equal to at least ½ of 1 per cent. of the cross-sectional area. The reinforcement shall be placed within ½ in. of the face of the block, and the bars shall not be more than 8 inches between centers, care being taken to place a bar in each corner or projection. Bars shall be hooped with bands or wires not more than 8 inches between centers.

PROTECTION OF CORNERS.

All corners and edges shall be sharp and well defined. They shall have true horizontal and vertical lines and no block will be accepted that is chipped or marred in any manner. **5. Blocks.**

CURING.

Natural Curing. For the purpose of securing proper curing, the blocks shall be protected from the sun and strong currents of air, shall be sprinkled at such regular intervals as necessary to **6. Curing.**

prevent drying, and such other precautions taken as to enable the final set to take place under the most favorable conditions.

At least twenty (20) days shall be allowed for curing.

Steam Curing. The blocks shall be removed from the molds as soon as the conditions will permit and shall be placed in an atmosphere of steam saturated with moisture for a period of at least forty-eight (48) hours. The blocks shall then be removed and stored for at least fourteen (14) days before use, being sprinkled three times a day during the first seven days.

Care to be taken to maintain the temperature at not less than 60 degrees Fahr.

LAYING.

7. Laying. Before laying, the various blocks and adjoining work shall be thoroughly moistened to prevent the absorption of water from the mortar. The mortar shall be composed of one part Portland cement, three parts sand and one part thoroughly slacked lime.

BLOCKS CAST IN PLACE.

8. Blocks Cast in Place. If the block is cast in place the forms shall be sand-papered, shellaced, oiled, and if necessary sprinkled. A 1:2 mixture one (1) inch thick shall be placed next to the forms and a backing of very wet concrete of 1:2:4 mixture added. In order to prevent checks and hair cracks troweling will not be permitted. All blocks shall be properly protected until accepted.

DISCOLORATION.

6. Discoloration. All blocks shall have uniform color.

National Association of Cement Users.

PHILADELPHIA, PA.

PROPOSED STANDARD SPECIFICATIONS FOR PLAIN CONCRETE DRAIN TILE.

MATERIALS.

Cement. The cement shall meet the requirements of the Standard Specifications for Portland Cement of the American Society for Testing Materials, and adopted by this Association (Standard No. 1). 1. Materials.

Fine Aggregate shall consist of sand, crushed stone, or gravel screenings, graded from fine to coarse, passing when dry a screen having ¼-in. diameter holes, shall be preferably of silicious materials, clean, coarse, free from vegetable loam or other deleterious matter, and not more than 6 per cent. shall pass a sieve having 100 meshes per linear inch.

Mortars composed of one part Portland cement and three parts fine aggregate by weight when made into briquets shall show a tensile strength of at least 70 per cent. of the strength of 1 : 3 mortar of the same consistency made with the same cement and standard Ottawa sand.

Coarse Aggregate shall consist of inert material, graded in size, such as crushed stone or gravel, which is retained on a screen having ¼-in. diameter holes, shall not exceed in the largest dimension one-half the wall thickness of the tile, and shall be clean, hard, durable, and free from all deleterious materials. Aggregates containing soft, flat or elongated particles, shall be excluded.

Water shall be clean, free from oil, acid, strong alkalies, or vegetable matter.

PROPORTIONS.

2. Proportions. A bag of Portland cement weighing 94 pounds shall be considered as one (1) cubic foot. All concrete shall be prepared and mixed in quantities requiring one or more full bags of cement, and the use of any device for mechanically proportioning the materials is prohibited.

Machine Made Tile.

8 ins. and less in diameter. Tile in sizes up to 8 ins. in diameter shall be made of a mixture of one part of cement to not more than four parts of fine aggregate (1:4).

10 to 16 ins. diameter. Tile from 10 to 16 ins. in diameter shall be made either from a mixture of one part of cement to not more than four parts of fine aggregate (1:4), or of a mixture of one part of cement to not more than two parts of fine aggregate and four parts of coarse aggregate (1:2:4).

18 to 30 ins. diameter. Tile from 18 to 30 ins. in diameter shall be made from a mixture of one part of cement to not more than two parts of fine aggregate and four parts of coarse aggregate (1:2:4).

Hand Made Tile.

8 ins. and less in diameter. Tile in sizes up to 8 ins. in diameter shall be made of a mixture of one part of cement to not more than four parts of fine aggregate (1:4).

10 to 16 ins. diameter. Tile from 10 to 16 ins. diameter shall be made either from a mixture of one part of cement and not more than four parts of fine aggregate (1:4), or of a mixture of one part of cement to not more than two and one-half parts of fine aggregate and four parts of coarse aggregate (1:2½:4).

18 to 30 ins. diameter. Tile from 18 to 30 ins. in diameter shall be made of a mixture of one part of cement to not more than two and one-half parts of fine aggregate and five parts of coarse aggregate (1:2½:5).

MIXING.

The ingredients of concrete shall be thoroughly mixed dry, sufficient water added to obtain the desired consistency, and the mixing shall continue until the cement is uniformly distributed and the mass is uniform in color and homogeneous. **3. Mixing.**

a. Measuring Proportions. Methods of measurement of the proportions of the various ingredients, including the water, shall be used which will secure separate uniform measurements at all times.

b. Machine Mixing. When the conditions will permit, a machine mixer of a type which insures the proper mixing of the materials throughout the mass shall be used.

c. Hand Mixing. When it is necessary to mix by hand, the mixing shall be on a water-tight platform and the materials shall be turned until they are homogeneous in appearance and color.

d. Consistency.

Machine Made Tile. For machine made tile the concrete shall be as wet as can be used and allow the immediate removal of the jackets. The concrete must be used within twenty (20) minutes after the time it is mixed.

Hand Made Tile. For hand made tile the consistency of the concrete shall be such that it will be forced into every part of the mold by jarring or tapping. The concrete must be used within forty (40) minutes after the time it is mixed. The use of concrete requiring tamping is prohibited.

e. Retempering. Retempering mortar or concrete, *i. e.*, remixing with water after it has partially set, shall not be permitted.

FORMING.

Under no circumstances shall tile be made in a temperature lower than 40 degrees Fahr. Tile shall be formed so as to prevent laminations or planes of weakness. **4. Forming.**

Machine Made Tile. The tile shall be made in such a manner as to insure a dense and uniformly packed product with smooth ends and inner surfaces and show water marks on the outer surface (web-like markings indicating free moisture).

Hand Made Tile. Concrete for hand made tile shall be forced into the metal forms by jarring or tapping in such a manner as will obtain a smooth, dense surface and shall remain undisturbed in the form for at least twelve (12) hours.

CURING.

5. Curing. *Natural Curing.* For the purpose of securing proper curing, the tile shall be protected from the sun and strong currents of air, shall be sprinkled at such regular intervals as necessary to prevent drying, and such other precautions taken as to enable the final set to take place under the most favorable conditions.

At least twenty (20) days shall be allowed for curing.

Steam Curing. The tile shall be removed from the molds as soon as the conditions will permit and shall be placed in an atmosphere of steam saturated with moisture for a period of at least forty-eight (48) hours. The tile shall then be removed and stored for at least fourteen (14) days before use, being sprinkled three times a day during the first seven days.

Care to be taken to maintain the temperature at not less than 60 degrees Fahr.

DIMENSIONS.

6. Dimensions. *Diameter.* The diameter or size of a tile shall refer to the inside diameter and be uniform in all directions. Tile with a diameter of more than thirty (30) inches shall be reinforced.

Thickness. The thickness of the tile wall shall be uniform throughout and shall not be less than one-tenth ($^1/_{10}$) of the diameter, with a minimum thickness of one-half (½) inch.

Length. The length of a tile shall be uniform at all points and not less than the diameter, with a minimum of twelve (12) inches, and a maximum of thirty (30) inches.

FINISHED TILE.

7. Finished Tile. Finished tile shall be free from cracks and other defects which will appreciably diminish their strength, and shall give a clear metallic ring when struck with another tile or with a hammer.

TOPICAL DISCUSSION ON CONCRETE PRODUCTS.

Mr. A. C. Raymond.—Our factory at Detroit, Mich., makes **Mr. Raymond.** concrete blocks and ornamental work of certain dimensions and sizes, all under a very heavy pressure. All our concrete stone and ornamental work, such as sills, lintels, coping and everything of that kind, whether rough or whether faced with white sand, granite, or limestone screenings or any form of facing, up to 66½ ins. long, are made under a registered pressure of 200 tons; and after being subjected to the pressure they are immediately immersed in moist steam. Certain larger sizes, 66½ ins. long, 20 ins. wide and 14 ins. thick, have to be made by ordinary hand tamped methods. We do the tamping in a steam room and do not move the product from that time until it is ready to go into the yard or on the job, having immersed it in moist steam immediately.

Now we have found most excellent results for this reason: that there is no loss of moisture by evaporation from the time the mixture is made until the block is cured; that is, until the initial set is complete. There is no loss by evaporation of the water of crystallization. The blocks, of course, when green are quite sensitive and tender, and the practice has been quite generally to let the blocks stand for several hours in order to obtain the necessary strength to stand the impact of water from a hose, or even a gentle stream, a fine spray. In using the steam curing process, as I explained here, you cannot disintegrate even the most tender face of the block, and as there is absolutely no loss of moisture, the result is a much denser, harder, more efficient product than by any other method with which I am familiar. I have taken blocks that have been made 25 to 30 days and broken them, having placed them out in the sun after being steamed 24 hours, and found the centers still wet, showing how thoroughly the moist steam permeates the concrete. Blocks so made show a very high crushing strength and are very low in absorption. I have tested blocks 24 days old, cured in that way, which have shown 1,941 lbs. per sq. in. crushing strength on a 9 in. height.

Mr. Raymond. Bear in mind that a piece of concrete 9 ins. high cannot stand anything like the crushing pressure that a 3 in. cube does, and 1,941 lbs. at 24 days and 9 ins. high is probably 2,500 or 3,000 lbs. on a 3 in. cube. Blocks made like that entirely submerged in water for 48 hours, being weighed dry before being immersed and weighed at the end, have shown a gain in moisture of less than 4 per cent. Now if the general character of factory-made concrete can be raised to such a degree of excellence as that, a great deal of the unfounded prejudice that exists against factory-made concrete ought to be swept away.

In regard to proportioning and mixing, I think no man in the concrete business should ever make a mixture without first studying the character of his materials and scientifically computing the voids. This is a very simple process by means of the water measurements, and if the voids in the sand are 33 1/3 per cent. which means the proportion of 1:3 of your cement, do not make it 1:4, because if you do it means that you have just that extra amount of sand which has no cementing qualities. Wherever that sand occurs in the block there will be a soft place and the block will be no stronger than the weakest spot in it. The same applies to the aggregates. The voids should be computed and the mortar made of the cement, sand and aggregates figured, so that the voids will exactly absorb or conceal that mortar, then you will have true concrete, that needs little or no waterproofing.

Waterproofing, generally speaking, I think is a sort of refuge for poor concrete. If concrete is properly mixed and cured, very little waterproofing is required, except on fine work.

I was hoping to hear some one give his experience with the use of hydrated lime as waterproofing. I suppose it is well known to most of you that the latest theory concerning the action of concrete or Portland cement in hardening is that it does not form crystals, but what is called a colloid, a jelly-like substance like glue. This action goes on for long periods of time, and is caused by the action of water on the free lime in Portland cement. Now if that is true, and that is the theory of the leading expert of the world, Dr. Michaelis, of Germany, then the use of hydrated lime as waterproofing only increases the amount of free lime in the

Mr. Raymond.

mixture over and above that of the cement particles, and tends to create that jell, so called, more freely and in a larger quantity than in acting alone on the cement particles. I am only outlining the theory, Mr. Chairman, and I would be glad to know if any one has had experience in waterproofing by the use of hydrated lime. Tests have been made by the University of Wisconsin and private tests, all of which tend to show that the German theory is correct, and that concrete is actually strengthened, I mean the crushing strength is actually increased by the use of hydrated lime.

Mr. Chandler.

MR. DANA G. CHANDLER.—I would like to ask as to what is the average temperature of your steam room.

Mr. Raymond.

MR. RAYMOND.—I do not know that we have used thermometers to ascertain that, but it is just as low as will overcome the friction of the pipes and carry the steam in the form of a vapor; no more heat than is necessary to produce moist vapor.

Mr. Chandler.

MR. CHANDLER.—How high must the temperature of the room be to injure the blocks?

Mr. Allen.

MR. H. B. ALLEN.—I think the quality of the cement used makes a difference. If it is a well-seasoned cement the temperature may run higher than if the cement is fresh or green.

Mr. Chandler.

MR. CHANDLER.—We are very careful about that. When our steam rooms get above 80 deg. we open them and turn on the hose, flooding the blocks. We have thermometers in each steam room and try to keep the temperature below 80 deg. In warm weather the temperature will rise, and we have found it a very good idea to turn on the water and flood our blocks, fill them with cold water. We get a better result and have found that if the temperature is allowed to get much above 80 deg. the blocks will turn white and get dry.

Mr. Allen.

MR. ALLEN.—In regard to the use of hydrated lime as a waterproofing compound, there is an allowable percentage that may be used, and above that long time neat tests or mortar tests, 1 : 3, show the briquettes to be weakened by its use. I think over 8 to 10 per cent. of hydrated lime will show a decrease in strength on a 28-day test, in 1 : 3 mortar, using standard Ottawa sand and well-seasoned cement.

Mr. Brooks.

MR. R. E. BROOKS.—Referring to steam curing it seems to me there is a theory that it is better to leave the concrete outside

Mr. Brooks. the steam room for a certain length of time before it is subjected to live steam. If there is any one who has an opinion on that point I would like to hear it. In our steam curing rooms we put the blocks in as they come from the machines, taking 2 days to fill one room. The first night the steam is turned in and the blocks are thoroughly saturated. The second day the room is completed and then it is steamed two full days. We use the exhaust steam from an engine, and the temperature ranges from 100 to 120 deg. We have excellent ventilation at both ends to help the condensation. The steam is let in through two pipes along the floor, so that it comes through the piles of blocks.

Mr. Chandler. MR. CHANDLER.—We have experimented both ways and have found it best to put the blocks into the moist steam as quickly as possible, keeping the action of the cement moving along. If you leave the blocks out and let them dry out a certain per cent. of the strength of the cement is lost, while if they are put right in and moisture added, better edges and beautiful blocks result. We have tried the experiment and find the best way is to fill the car and shove it into the steam room. We use cars and steam rooms, 4 x 5 ft. in section, just wide enough for the cars. The cars run in, one right behind the other, and the steam kept on the blocks 48 hours. Our experience is to give the blocks the steam as soon as they are made, not wait and let them dry out.

Mr. Raymond. MR. RAYMOND.—Our steam rooms are made of cement blocks of our own manufacture. They are 22 ft. long, 17 ft. wide and 7 ft. high, and hold from 250 to 300 sq. ft. of wall, either 12 or 8 ins. thick. We make about 1,000 wall feet per day and each of the steam rooms should fill in 2 or 3 hours, and then the steam is immediately turned on.

Someone spoke of the desirability of putting the blocks into the steam quickly. Ours are always immersed in steam within 2 or 3 hours after they are made, and the latest of them, of course, within a few minutes. Now the reason why blocks are kept outside of the steam rooms for some time is that those who have to sprinkle the blocks cannot do so on a perfectly fresh block. It would disintegrate the surface of a fresh block, under even a light spray; so the blocks are kept out of the steam until the initial set occurs. The worst thing that can happen to a block

is to have the initial set occur under a constantly decreasing moisture due to evaporation. There ought not to be a moment lost from the time the block is made until finally cured so that it has all the water it can take. The initial set occurs at various periods, 4, 6, 8, to 10 hours, depending on different brands of cement. If the initial set takes place under drying conditions you will never get good results. **Mr. Raymond.**

The steam rooms are made simply with a roll of canvas for a door on the front, and ordinary wooden barn doors, running on a track opening out into the yard. We do not use rack cars or transfer cars in our establishment. The blocks are taken directly from the machine in a steel car about 6 ft. long which constitutes the mold box and runs on a track laid on a wood girder on each side of the steam rooms, grouped opening directly on the track. It takes four men to unload a car, two on each side, our blocks are rather large, 32 ins., and weigh probably 110 or 115 lbs. when they are green. They are taken from the car and carried by hand into the steam room and laid on a rack and are not disturbed again, so we save the large expense connected with equipping the plant with rack cars and tracks. We also avoid the jolting of green blocks on cars. We do not have a broken block day after day, because they are handled by hand and gently placed on the racks.

Mr. Wesley L. Crawford.—In mixing concrete I always use 10 per cent. of hydrated lime and the result is that with proper curing a block is so hard that I can immerse it 1 in. deep on the face in water and keep it there for 3 months, but the moisture will not penetrate to the hole in the block. The blocks are immediately put on a car and run into the steam rooms. We endeavor to use such quantities that the mixture is not more than 15 to 30 minutes old before it is in the steam. I have found by experience that there is something besides steam and moisture needed to cure a block. Just before a thunderstorm on a hot afternoon in the summer the set in blocks cured outside seems to be more permanent and hard than in a dry day. I use a gas engine and the exhaust from the gas engine is largely composed of carbonic acid gas. I have two steam rooms 18 by 30 ft. and introduce the exhaust from the engine into this room, dividing the exhaust so **Mr. Crawford.**

Mr. Crawford. that each room is supplied. I hardly agree that a low temperature is desirable. About 100 or 110 deg. have given me the best results. In fact I have introduced some heating coils in the room used in the winter time to keep the temperature up. Of course in summer that is not necessary. I believe a block made as wet as possible, properly tamped and proportioned, with 10 per cent. of hydrated lime, comes nearest to giving a waterproof block. I have discarded the use of waterproofing compounds, because my experience has not been satisfactory.

I would like to know if there is any one here who can give us information about the temperature of the steam room. I wish we might have more information on that subject. I heartily agree with Mr. Chandler that the quicker the product is placed in a moist atmosphere after the cement is mixed, the better are the results.

I endeavor to leave the product in the steam for 48 hours. I have found that gives the best results.

Mr. Stowers. MR. CHARLES A. STOWERS.—I would like to ask as to the manner of handling the blocks in cold weather coming from the steam room. Can they be put right out doors without bad effects to the block?

Mr. Crawford. MR. CRAWFORD.—I would say that after the blocks have been in the steam 48 hours we find no trouble in putting them out even in zero weather. I am very careful to have 48 hours of good steaming before they are exposed to cold weather.

Mr. Stowers. MR. STOWERS.—That has been my experience. This is the first winter I have tried it, and was rather afraid.

One of the speakers referred to curing blocks and taking them in the yard in any kind of weather after only 24 hours in the steam.

Mr. Raymond. MR. RAYMOND.—Only 24 hours in the steam, and then hauled to the yard in any kind of weather.

Mr. Allen. MR. ALLEN.—I think this whole question at the present time is hinging around the same requirements for storage of briquettes for testing strength found in the Standard Specifications for Testing of Cement. When making up cement briquettes to test the strength of cement the briquettes are always placed under damp cloths or in moist closets to obtain the actual strength

as quickly as possible and yet at a uniform temperature. Now if the heat is increased on cement blocks the set will occur quicker. You are going to get an early strength quicker, and then the strength may drop back faster. A steady gain in strength in the block will not result, only a quicker gain, which might perhaps be lost later. I think that the set of the block should go on naturally and progressively and not too rapidly. I think if some of the blocks were placed in different temperatures for different periods, that is, at a high temperature and a low temperature, and seasoned by steam, it would be found that the blocks cured at a low temperature would be higher in the ultimate strength obtained and a strength with a gradual and a steady gain rather than a quick gain and perhaps a falling back in strength afterwards. **Mr. Allen.**

MR. EILBACHER.—We obtain good results in steam curing with a tube about 7 ft. sq. (7 ft. wide, 7 ft. high), with a flat ceiling entirely coated with cement on the inside, making it practically airproof, a pipe running down along the center of this ceiling the full length of the tube, branching out from this pipe with various smaller pipes to the side walls at intervals of about 5 ft. These are carried down to the floor level of the tube, with small petcocks so that they can be regulated according to the disposition of the product on the inside. We do not make any special effort to raise the temperature in the steam room, but find that we get good results by keeping the temperature between 65 and 80 deg. We have thermometers arranged so that they can at all times be seen through pieces of glass imbedded in the wall near the ceiling. This particular tube is constantly coated with water, so that the top layers of the blocks on cars are really sometimes pitted with small drops. The blocks that happen to be the last ones made are naturally on the top rack of the car and receive some of this dripping from the ceiling. **Mr. Eilbacher.**

My theory in the matter is, as the result of actual experience, that as long as the moisture is supplied at a steady temperature, between 65 and 80 deg., good results are obtained.

I would like to hear as to how long the blocks are usually kept outside before they are ready for use. We have in some instances taken blocks out of the steam room and transported them to

Mr. Eilbacher. the work, ready to put into the wall in 4 days after they were made. Whether that is really good practice I do not know. I have had no complaints and have noticed no particular defects in the blocks, but I do not altogether know whether it is a practical thing to do in the wintertime. I have noticed in the specifications for concrete blocks, that blocks, after being steam cured, should be kept moist and sprinkled for a period of 6 or 7 days, which seems to be altogether unnecessary.

Mr. Wiselogel. MR. W. F. WISELOGEL.—As we are about to install a plant I would like to inquire of those who have steam rooms as to what is the most economic height, say in feet, above the track, to give the best results, and whether you should use a perforated pipe or simply turn the exhaust into the steam rooms. We will say the steam room is wide enough for two cars, with a passage.

Mr. Brooks. MR. BROOKS.—It has been our experience that if the temperature runs over 120 deg., the moisture seems to go out of the block and it crumbles so that we try to keep the temperature below 120 deg. and find the condensation is better and that a little ventilation helps to condense the steam. I think with the temperature at 150 deg. it would take out the moisture and you would not get the proper amount of condensation.

Referring to the size of the room I would say that our steam rooms are arranged in the following way. One side is 8 ft. in height, the other is 6 ft. with a slanting ceiling to carry off the moisture. The steam room is 50 ft. long and 14 ft. wide. We tried to get the ceiling as smooth as possible, so that the water would run down, and in case we had a green product, the drops would do no injury.

Mr. Stowers. MR. STOWERS.—Our steam rooms are of monolithic construction with reinforced concrete columns. There are three tracks taking four cars each. The ceiling over each track is in the form of an arch with a span of 4 ft. 6 ins. The center of the arch is about 6 ft. above the track and the spring of the arch is sufficient to clear the top layer of blocks on the car so that there is no danger of breakage. The small arch is advantageous in that there is only a short distance for the condensed moisture to run off. A room 8 ft. high on one side and 6 ft. on the other would require a long slope, and I find that the condensed steam will drop from

all parts of the sloping ceiling instead of running off. We have very little trouble with the condensed moisture dripping on the blocks, and only at infrequent intervals do we find a pitted block, which is, of course, not sent out. Mr. Stowers

At the present time we are using narrow cars which take one row of blocks; the largest one being 24 ins. That is all very well when you are making 24, 16, or 18 in. blocks, thus filling the pallets. However, if you are working on 16 in. blocks, only 28 blocks will go on one car in 3 days. We have been recently reconstructing our cars. We drilled our racks 9½ ins. apart all the way down on each side and put in a piece of pipe with cotter pins in to keep it from slipping, using set screws about 4 ins. from one end. We also changed the size of the pallets, using boards 1 in. thick with a ¾ in. cleat nailed on each end, all nailed on exactly alike. The blocks are carried from the machine to the car, which is in a pit, so that it is not necessary to lift high for the last deck, slip the block on and move it in until the cleat hits the adjusting nut on the end of the pipe. This places the block exactly in the center. One reason I am particular is because our tunnels are a little narrow. If you do not get it very nearly right the cars will not go in. The cars, instead of carrying 28 blocks, as formerly, now carry 54 16 in. blocks, so we have practically doubled the capacity of the steam room without adding more cars to the equipment. The work was done in our own shops.

I think it is a very good scheme for every block manufacturer to have a little machine equipment in the shop, such as drills and a few other machine tools, so that it is not necessary to go to some outside shop for repairs. We have made changes on our cars right in the plant without interruption in the business, and we can have the use of the car until we get a chance to finish it.

I believe we have the best shape of tunnel and form of steam room there is. I have not yet seen a better nor safer form to prevent dripping of water on the product.

Mr. Raymond.—I think the shape of the steam room generally depends on the class of business that develops in your community. Now we make more dimension stones than blocks; the Mr. Raymond.

Mr. Raymond. blocks are a secondary consideration. Our factory is now running every day on dimension stone and we turn out from 600 to 800 lin. ft. of sills, lintels, coping, belt courses, water-tables and other trim, in competition with natural stone.

Our steam rooms are 17 ft. wide and 22 ft. long. We take the sills from the machine after subjecting them to a 200 ton pressure and carry them directly into the steam rooms. In order to save room, we tier the sills, water-tables, etc., 3, 4 or 5 ft. high, after which they are cured in steam. We have motors, using current from the Edison Company, and having no engine, make our steam as an independent matter from a 25 horse-power upright boiler, just like a big stove, and that is all we require to produce the steam. For block making purposes only, I imagine that a tunnel-shaped steam room would be the best. Dimension stone work is the most profitable part of the business, and one that is rapidly coming to the front, because you can face your stone in any colors and produce any texture you desire fully equal to that of the best limestone. I am making concrete of white silica sand without waterproofing, which is denser than Indiana Bedford stone. If any of you gentlemen think that this is an astonishing statement I will be glad to show you at the exposition samples of our concrete and compare them with Indiana limestone and other natural stones. I believe that well-made concrete is not only equal to the best natural stone, but better.

Mr. Crawford. MR. CRAWFORD.—I would like to ask those who are accustomed to making blocks, especially, what their experience has been with the wooden pallet and the iron pallet. I have found by experience that with the wooden pallet it is almost impossible to move a block without starting very small cracks, which weakens the block, and there seems to be no remedy. Using the iron pallet there is absolutely no cracking.

Mr. Raymond. MR. RAYMOND.—Our blocks can go into a building in 36 hours, and they are hard enough to carry the weight that would be imposed upon them. Now during that hardening process there is a slight shrinkage in all concrete, no matter how heavily it is pressed or whether steam cured, sprinkled or otherwise. The effect of that is not disastrous to the strength of the wall, but if these blocks are laid in the wall too soon your mortar joints

will show cracks for the block does contract slightly. I think it is estimated that in 30 days the ordinary block will contract 1/16 in. in setting. It is liable to pull on the mortar joints, but other than that I do not think there is any danger in using blocks promptly. Still, to guard against all contingencies, I should think it would be well to allow about 2 weeks for the hardening of steam-cured blocks. Then you are sure, and in that period the shrinkage has gone on to such an extent that the subsequent shrinkage for 2 weeks more will probably not affect the mortar joints much. **Mr. Raymond.**

Now as to pallets. We use in our dimension work very large pallets, maple or Georgia pine or southern pine or Norway, about 2 ins. thick and 5½ ft. long. We make large numbers of stone 5½ ft. in length, and all are made on a single wood pallet. Now these pallets must undoubtedly be kept in good condition or they will warp and thus crack the stone as Mr. Crawford said happens to much of his work done on a wood pallet. We never use iron pallets with these large dimensions; they would be too heavy.

Mr. Stowers.—Speaking of the shrinkage of blocks, I have a factory building in Akron, Ohio, where I put up a temporary building and built my factory of blocks made on the ground. A geat many of the blocks went into the building 48 hours after they were made, with the result to-day that shrinkage that has taken place and loosened the mortar and you can see daylight. It is very slight, but it is there. **Mr. Stowers.**

Mr. Raymond.—Our method of introducing the steam is through small holes. The pipe comes from the boiler up to the center of the ceiling, and then pipes run down to the sidewalls to within about 16 ins. of the floor of the steam room. Then pipes run the whole length of the wall, within about 16 ins. of the floor, perforated every 4 ins. downward, so that the steam when it emerges from the pipe enters the steam room in an oblique direction from both sides, and the jets rise through the blocks. I do not think that the manner of the introduction of the steam is one of such great importance, as the steam condenses on the blocks, thus feeding it gently with water. The blocks at first are very much colder than the steam and remain colder than the steam for a **Mr. Raymond.**

Mr. Raymond. considerable period; wherever the steam touches the block it condenses into a drop of water which is absorbed by the block later.

I think this is the explanation of the advantage of the method of the gentleman who stated that every little while they let out a little heat and flood the blocks with water. I think that simply cools them and enables them to condense the steam more freely when it is back again. I do not believe it makes a great deal of difference in what way the steam enters the steam room, as it will go at once to the top. The main thing is that it shall be so introduced as to gather around all the blocks and condense upon them.

Mr. Chandler. MR. CHANDLER.—We introduce the exhaust steam from the engine inside of the steam room under the track, pipes leading both ways under the car and discharging the steam lengthways. The steam rises, fills the upper part of the steam room and then condenses and settles. When the steam is started in the steam room it can be seen to pass right up through the car and the blocks. Our steam rooms are 4 ft. in width, between 5 and 6 ft. in height, and each steam room contains six cars. When we want to empty a steam room we keep the doors open for a short period, as the blocks dry off much better to handle. As has been said, I do not think there is very much difference as to the way the steam is admitted, as long as it is well distributed and not too hot, and with plenty of moisture.

Mr. Christopher. MR. J. H. CHRISTOPHER.—I would like to have the opinion of those present as to whether it is necessary, after a block has been cured for 24 or 48 hours in the steam room, under proper conditions, to wet the block afterwards in the yard?

The President. THE PRESIDENT.—The Chair would say that steam curing properly done should leave the product in a wet condition. If the temperature is so high that the block comes out dry, the damage has probably been done in the steam room itself. On the other hand, the difference in temperature between the steam room and the air may be such as to cause a rapid evaporation of the water. But if the curing has been properly done in the steam chamber, then there can be no material damage done to the block, for the reason that the hardening has already proceeded and given the strength which would ordinarily be obtained in 30 or 60 days. You would not ordinarily wet a block at the end of 30 or 60 days,

but if the difference in temperature is such that there is likely to be a rapid evaporation of water it might not be a disadvantage to sprinkle it. The Chair is of the opinion that if properly cured no sprinkling is necessary. **The President.**

The object, of course, of steam curing is to obtain in a short time a strength which, under natural conditions, it might take weeks to attain. Now I believe it is good practice to allow the initial setting of a cement to start under natural conditions and a certain strength to be obtained in the product before this artificial acceleration is given to it. The reason for putting the product into the steam chamber is simply to supply heat, which increases the rapidity of the chemical action of hardening. If you have heat alone you get a dry atmosphere, which takes from the product the water which is necessary for the hardening, so you manifestly must have moisture, and I think the best results are obtained by allowing the product to cure normally or set normally for 12 hours, at least, perhaps 24 hours, and then to be put in the steam chamber, although it is a fact that the product can under proper conditions be placed directly in the curing chamber without any detrimental results.

Mr. Stowers.—One of our members has spoken of periodically sprinkling his blocks after they are put in the steam room. I do not believe it is a good idea and I would like to have our President give us his opinion. It seems to me that this would lower the temperature, and unless the water has been heated it will certainly lower the temperature of the blocks, and will not this retard the chemical action? Is it not better when you once put them in to let them go right straight along and depend on the condensation of the steam to give the moisture, instead of sprinkling and putting steam on again. You get the same results as curing in the air if you sprinkle a block and cool it off. In air curing the block cools off at night and in the morning the temperature has to rise again before the process of curing goes on. That is why it is it takes so long to cure a block in the air. You get the results in a few hours by steam curing (only because you keep the temperature steadily at one point), which you naturally get in days by putting the blocks outside, where the temperature is constantly varying. **Mr. Stowers.**

The President. THE PRESIDENT.—The President wants to correct the impression that he is a manufacturer of cement products; he is only interested in the theory tested experimentally, under conditions as near as possible comparable with manufacturing conditions.

The steam-curing chamber is variable in action depending on its size; for example, if you had a chamber the size of this room and turned in live steam and attempted to obtain a saturated atmosphere, you would find that it might be saturated near the floor where it was damp and cold, while you would have heat up at the top, and it would be dry. So in a curing chamber you may have conditions under which your product at the top is drying out while at the bottom it is perhaps being properly cured. If that is the condition then your curing process is imperfect. An attempt has been made to resort to spraying to compensate for this defect in the process of curing. I agree that it is not a proper thing to sprinkle during the process of curing. If your product is green you will certainly have to provide some way of preventing water from coming in contact with it, otherwise it is going to pit or mark the product. The best results can be obtained by having low pressure steam, that is thoroughly damp, so that when the chamber is closed the air is so moist that condensation occurs all over. Under these conditions proper curing is obtained. It depends largely on the size of the product that is being cured as to whether or not the temperature changes will have any important effects. The low rate of heat conductivity of concrete is such that it is not readily susceptible *en masse* to ordinary changes in temperature. So that if the curing once gets well under way the heat developed by the chemical process of hardening supplies a certain amount of heat. You can accelerate the initial process by a temperature sufficient to start and maintain hardening. The advantage of proper steam curing where the air is uniformly moist, is that the product comes out with a uniform color, which may not be the case if it is attempted to spray.

Mr. Stowers. MR. STOWERS.—I would only say, if we are going to attempt to steam cure at all, if our steam rooms are not built so that we can get practically a saturated atmosphere, we had better build them so it can be done. That is the principle on which I build

my steam rooms, and if they were not that way I would endeavor to have them that way. **Mr. Stowers.**

Mr. Chandler.—I am the one that started the idea of spraying, and if I am wrong I want to be set right. I discovered that when my steam rooms reached 100 deg. that my blocks were dry. I then opened the doors and sprayed the blocks with water to bring down the temperature and also to moisten the blocks. We endeavor to keep below 80 deg., and find that it is a pretty good idea during the hot season, and the blocks will stay in better condition. I do not leave my steam rooms open for a period of time, not giving them any heat whatever. We simply water the blocks, and that cools them off to below 80 deg. Then the doors are closed and the low pressure steam exhaust turned on. I have had exceedingly good results that way. **Mr. Chandler.**

The President.—The Chair would call attention to the fact that when you open up the steam rooms you let out the moist air. You are defeating the very purpose you are trying to attain. If your steam room is so designed that it will not properly cure the blocks without spraying, you should change it. You never should have a condition in the steam rooms that the blocks get dry, because the very moment they get dry you are going to seriously impair the strength of the blocks. **The President.**

As to the degree of temperature, some people think that 80 deg. is better than 100. That is a mistake. It is not a question of pressure, but it is a question of a uniform moist heat the essential being that it shall be a moist heat. If it is a moist heat you cannot have drying out and there is no necessity for spraying; and if you cannot get a moist heat then do not cure with steam.

Mr. Stowers.—I would suggest that the gentleman who has just spoken has too much exposed pipe in his steam rooms, and that is where he gets the high temperature. There is radiation from the pipe before the steam gets out to the atmosphere. We find in our steam rooms that the best results are obtained by simply having a pipe run down along the side, the end run through from a T with valves to shut it off from the pipe. We have no radiation whatever from the steam pipes inside, except perhaps 4 or 5 ins. of pipe projecting inside the tunnel. We **Mr. Stowers.**

Mr. Stowers. never have anything like 100 deg. inside the tunnel, and if I distributed it as suggested and the heat still came up in the cars, I should certainly bury the pipe in the ground and bring it up to the surface with a short end and to a considerable extent save the drying due to radiation.

Mr. Raymond. MR. RAYMOND.—Our President made a statement a few minutes ago which I think might leave a misleading impression, and I would like to call attention to what seems to me is a misstatement. He mentioned a few moments ago the desirability of letting blocks harden naturally for certain periods before being introduced into the moist steam, 10 or 12 hours. Now the opinion expressed here by every one before you came in, was that they should be put into the steam at the very earliest moment; and I would like to ask his professional opinion. When you make a test block in the laboratory, then you put it under water, where it is kept constantly saturated in order to make high-class concrete that will stand a high test. If you can approach that with factory-made concrete you are reaching pretty nearly laboratory conditions, which are the ideal.

Now my experience and the experience of several others is that the quicker the concrete is placed in the moist steam the better. We turn the steam on our concrete blocks within 1 to 2 hours for the longest period and 5 minutes for the shortest. We do hand tamped work in the steam rooms, take the molds off, and do the patching or trimming with a trowel, leave it in the kiln and turn the steam on immediately. We find very strong and hard feather edges on our ornamental work treated in that way, and our blocks, even at 24 days show substantially 2,000 lbs. compressive strength per sq. in.

Now I am afraid that the statement that he made of the desirability of hardening naturally may go out to the concrete fraternity generally, and they will think that that is the best way to cure the block; and I would like to have him state, if he will, in view of the fact that the initial set is complete in say all the way from 2 to 6 or 8 or 10 hours—now during that period, if there is no loss by evaporation of any moisture, but all the additional moisture that the block will take is fed to it, will you not get a far better result than to lose during a period of 12 or

24 hours—and he mentioned 24 hours—a portion of the water that is necessary for the formation of the crystals? Mr. Raymond.

The President.—I think Mr. Raymond has raised some very good points, and I think my statement does need an explanation. We sometimes are prone to look at things from a theoretical point of view and overlook practical conditions. Now in the ordinary cement product plant, at full blast in the summer, when the air perhaps is hot and dry, it would certainly necessitate keeping the block damp or moist, as Mr. Raymond has said, in order that the proper preliminary hardening shall take place; if that is difficult, troublesome or not convenient, then I quite agree with Mr. Raymond that probably better results would be secured by putting the product immediately into the steam chamber. But in making that statement I neglected to say that in keeping it for a period of 12 hours—and I fixed that approximately, because ordinarily the product would be made to-day and to-morrow, at a convenient time, which might be 10 or 12 hours, depending on when the product had been made and when it went to the steam chamber—the product must necessarily be in moist air, unless it so happened that during that period the natural air was sufficiently humid to supply the block with the moisture which is necessary for the hardening. The President.

In the experiments which were made under my direction on steam curing we did find that the preliminary natural curing for a period extending from one day over to the next was beneficial. We find, of course, alluding now to the laboratory conditions under which cement is tested, that to secure uniformity of test it is necessary to preserve the test piece for the same period, or at least until the initial set has occurred in moist air. If it is allowed to cure under natural conditions, the natural conditions that promote curing are conditions in which the air must be moist. If the air is hot and dry it is not in the proper condition for natural curing.

Mr. Crawford.—There are two questions I would like to ask the Chair. I referred to the use of carbonic acid gas in connection with curing blocks, and as you have said 100 deg. of heat was too much, will you kindly tell us what is the proper temperature to get the best results in steam curing? Mr. Crawford.

The President. The President.—I do not think that can be answered. But what I do want to convey is that it certainly ought not to exceed 100 deg. While our experiments are not completed they seem to indicate that an exhaust steam at a temperature of less than 100 deg. is best, and the pressure should be quite low. Of course, the higher the temperature, the heating of the block has a tendency to draw the moisture from the air and the block. So that you want a gentle temperature which accelerates the hardening without producing a condition of drying. I cannot answer that authoritatively; I do not know. But I certainly would say that it is not desirable to go beyond 100 deg.

WATERPROOFING CONCRETE WITHOUT ALTERING ITS APPEARANCE.

By Cloyd M. Chapman.*

While in search of a suitable material, coating or treatment to be applied to the surface of porous outer walls of concrete block or monolithic structures to prevent the absorption of water during rain storms, and the consequent dampening of the inner surfaces of these walls, a series of tests have been undertaken by Westinghouse, Church, Kerr and Company of New York. The purpose of these tests may be stated as follows:

To find a material, which, applied to the surface of a structure already completed, whose walls were of such porosity as to absorb water during rain sufficient to dampen the interior of the walls, would render that outer surface waterproof without materially altering the natural color or appearance of the concrete blocks or monolith.

There are a number of processes upon the market which claim to accomplish this desired result; in fact so great is their number and so wonderful their claims that we were at a loss to know which to select and so decided to test them all. To fulfil the requirement that the appearance of the structure should not be altered it was necessary that the waterproofing material be of the nature of a colorless solution or wash, and not of the nature of a paint or enamel. This requirement at once eliminated from consideration the many so-called waterproof paints and cement coatings containing pigments of whatever nature. For however closely a paint may approach the natural color of the concrete it always changes the appearance of the surface to which it is applied, as a concrete structure is not of one color throughout. We secured 19 samples of compounds made by 14 manufacturers, which the makers claimed would do just what was required. The method of testing was as follows:

* Engineer, Westinghouse, Church, Kerr and Company, New York, N. Y.

A number of cubes, about 3 ins. each way, were molded with a depression on one side large enough to hold about 40 cu. cm. of water. These cubes were made of a rather dry mixture of one part of Portland cement and three parts of crushed granite, by volume. The crushed stone was screened through a 5 mesh screen, and contained all sizes of particles from impalpable powder to pieces just passing the screen, all as it came from the crusher. The resulting cubes were very porous and absorbed water greedily. After these cubes had thoroughly set, being kept moist while setting, and had dried out, they were tested for porosity by filling the depression with water, and noting the time required for the cubes to absorb it. As the cubes were hand molded and rammed, they were not all of the same density, and any cubes which required more than one minute to absorb the water were rejected and not used in the tests.

After allowing the cubes to again thoroughly dry out, the side having the depression or cup was given a liberal soaking coat of the waterproofing compound under test. Only the one surface of the block was coated. No compound was applied to the block except to the inside of the cup and the remaining flat surface around the cup. This first coat was allowed to dry and a second liberal coat or as much as the concrete would absorb, applied. In some cases very little compound would be taken in at the second application. In other cases it appeared to take as much for the second as for the first coat. After the second coat had dried a test of its efficiency was made as follows:

Thirty cu. cm. of water were placed in the cup, a watch glass placed over it to prevent evaporation, and the bowl left undisturbed until the water was wholly absorbed by the concrete. The time of placing the water in the cup was noted and the time when it was completely absorbed. As the size of all the cups was the same and the amount of water measured, the area of surface exposed to the action of water was the same in each case. All other factors being approximately equal the efficiency of the waterproofing compound was proportional to the time required for the water to pass through it into the porous body of the block.

After this test the cubes were placed on a roof exposed to

the action of the weather for a number of months, and again tested as before with 30 cu. cm. of water, and the time required for complete absorption noted. Again, they were placed on the roof where they now are awaiting further tests. The action of the weather does not seem to improve many of them.

Of the 19 samples tested, on the first test, that is before being exposed to the weather:

5 required less than 1 hour to absorb the water;
4 took more than 1 hour, but less than 1 day;
7 stood more than 1 day, but less than 1 week;
3 held the water for more than 1 week.

After exposure to the weather for several months the following results were obtained:

7 stood less than 1 hour;
11 more than 1 hour, but less than one day;
1 held the water for more than 1 day, in fact 9 days.

In the case of one compound only one coat was applied, as the maker stated that one coat was all that was needed; one coat would do the work perfectly and any more would be useless. This article, after exposure to the weather, lasted just 27 minutes.

Now, as to the appearance of the treated surfaces. All of the makers presented their samples with the claim that they would not alter the color of the concrete. Of these 19 preparations, 9 darkened the concrete surface to which they were applied, 1 made the surface lighter and the remaining 9 had little if any effect upon the color.

DISCUSSION.

Mr. Laughlin. MR. A. H. LAUGHLIN.—I would like to ask whether a cement block, properly made and of good material, requires a waterproofing compound at all? Will it not shed water?

Mr. Chapman. MR. CLOYD M. CHAPMAN.—The circumstances which brought about the tests answer this question fully. When the power-house at Cos Cob, Conn., the plant furnishing power for the electrification of the New York and New Haven Railroad between New York and Stamford, Conn., was built, it was found to be so porous that something had to be done to the walls. The moisture came through the walls and ran down on the inside, endangering the electrical apparatus at its 11,000 volts. We presumed, of course, that the concrete blocks were porous and set about to find some treatment that would damp-proof them without altering the appearance of the building, to beautify which a great deal of money had been spent. The blocks were made of a dense, rich facing, with a leaner backing, on a face down machine, of a dry mix. Some of these blocks were taken to our office, the faces cut off of them, and various coatings applied to the block. Water was then applied to the treated faces, and the percolation or absorption noted. As a check, some untreated blocks had water applied to them in the same way, and it was found that there was very little percolation or absorption in the untreated blocks. The fault was not in the blocks; the entire fault was in the mortar between the blocks. The result was that the remedy we had to apply was to take out a little of that mortar between the blocks in the wall, which we did easily and rapidly with a small pneumatic tool and repointed with a mortar which was waterproof. The result was quite satisfactory.

This paper was prepared very largely with a view of presenting a simple method of testing waterproofing compounds which anybody could use and could draw their own conclusions. This test is simple. It does not require a great length of time, and an individual or a company having frequent use for such an article

could within a month's time come to a determination of their own as to what was good and what was bad. Mr. Chapman.

THE PRESIDENT.—The Chair does not think it desirable to discuss the merits of the particular compounds, the essential thing in this discussion is, of course, the results of tests and the methods used. The Chair would call attention to the time element in testing waterproofing compounds. Many waterproofing mediums that apparently are quite efficient at the beginning of the tests, after a year or more, begin to show a decided decrease in efficiency and in many cases the efficiency disappears completely. In the Chair's opinion probably 75 per cent. of the compounds on the market at the present time are worthless as permanent waterproofing mediums; there is undoubtedly a great deal more to the subject of waterproofing than the behavior under laboratory tests, and data obtained from the results of tentative tests of a few months duration are interesting but of little value in estimating the permanent value of the material under test. But, after all, the Chair believes that a well proportioned, well balanced concrete, properly mixed and placed will give the requisite density for the desired water tightness. Where concrete is improperly proportioned and placed, or where the process of manufacture does not admit of a dense product, it may be necessary to resort to the use of one of the numerous compounds in order to secure a water tightness that will make the product suitable for the purpose for which it is intended. The Chair believes it to be a fact that if such materials are used it is evidence that the process which makes this use necessary is defective and that means should be taken to remedy it as will render the use of waterproofing compounds unnecessary. Of course, I appreciate the fact that there are conditions where some elastic medium must be used in connection with the walls of a structure so as to prevent the flow of water through the construction joints or other unavoidable openings. The President.

MR. CHAPMAN.—It might be added that some 25 compounds are now under test which have not been exposed a sufficient length of time to give the results in this paper. They were exposed last fall, and I do not consider that they have been out long enough to furnish a sufficient test. Possibly next year we may Mr. Chapman.

Mr. Chapman. give the results of some 50 or more compounds, and further tests on these same compounds. The time was not specified in the paper because they have not all been out the same length of time. The first were exposed about 2 years ago, the last 6 or 8 months ago.

The President. THE PRESIDENT.—I would like to add another word on this subject, that is, that the Government has been experimenting with waterproofing compounds and at the present time has some 64 under test. The preliminary report on the tests of 40 of these compounds, extending over a period of one year, is now in progress of publication. These tests involve a study of the resistance of the material under various pressures and also as a damp-proofing medium as described by Mr. Chapman. This latter, of course, is a study of the ability of the material to insulate cement mortars and concrete against dampness.

Mr. Werking. MR. FRANK D. WERKING.—I have been in the block business on a fairly large scale for 5 years, the last 3 years using a face-down machine in connection with an upright machine. It is my candid opinion that the best dry block made is not waterproof. I make blocks with a 1:4 back and a 1½ heavy face, and have never yet found a block that would prevent moisture from penetrating through an 8 in. wall. I have built a number of houses, and after the first house have always studded the walls. During the past summer I have been experimenting with white lead, and it certainly does shed water. I do not believe that tamping, with a rich material and dry process, will produce a waterproof block, and it seems necessary to use the dry process in order to obtain a nice block.

Mr. Clark. MR. FRANK E. CLARK.—I have followed practically in the footsteps of the New York and New Haven Railroad, that is, the blocks made at Cos Cob station power-house, by taking the stone and having it ground fine and using a 1:2 mixture, there is practically no absorption whatever, using an automatic tamping machine. I have sold, within the last year, about 180,000 blocks, and now have orders for 1,200,000 blocks. This almost speaks for itself that the material naturally must be nearly waterproof, as no waterproofing whatever is used, but only ground granite in making the mixture, and first-class cement.

MR. WALTER F. BALLINGER.—As was pointed out by Mr. Chapman, one thought seems to have been lost sight of. The moisture in that case came through the joints and not through the blocks. We had similar experience with brick walls, a shale brick, which seemed to be particularly dense and non-absorbent, and yet the inside of the 13 in. walls was quite damp. I think the very fact that the brick was so dense was the cause of the dampness inside, that is, the mortar did not take hold of the brick to the same extent as it would with a brick which absorbed moisture. We noticed that the mortar appeared to shrink away from the brick. I think if the brick had been an ordinary clay brick and would absorb a moderate amount of moisture there would have been no trouble with the moisture on the inside of the wall. In fact, we have had no trouble in any case where the ordinary brick was used. **Mr. Ballinger.**

COST AND ADVANTAGES OF CONCRETE DRAIN TILE.

By J. H. Libberton.*

The manufacture of concrete drain tile necessarily resolves itself into three main divisions: those which are made by machine using a rotating trowel; those which are tamped, either by hand or machine, and those which are poured.

There are two different methods of manufacture for tile made by a rotating packer-head, the distinguishing feature being in the packer-head itself. In one case the packer-head is split into two sections, the upper portion being called the packer and the lower the trowel. The trowel rotates at one-half of the packer speed, the idea being to give a dense mixture and a smooth inner surface with as little wear on the head as possible. The other method of troweling tile into shape consists of using a one-piece packer-head obtaining much the same effect as with the one split into two sections. It should be the object of any machine to so compress the concrete that when the jacket is removed the tile will stand on either end. With some heads it is necessary to stand the tile on the upper end as it comes from the machine, since that one is packed better than the lower.

Under the division of tamped tile are found those made by hand and those made by machine. The hand method is not recommended since it does not tend to produce tile which are uniform. The fact that the material is tamped in layers is apt to produce planes of weakness which materially affect the quality of the finished product. The personal equation also enters, and in all probability the tile which were made in the morning are of a better quality than those which the workman rams up in the evening after a hard day's work. Mechanically tamped tile are proving very satisfactory and are made by a machine which revolves the inner and outer jackets, feeding the concrete in meanwhile. A tamper working up and down at about 300 strokes per minute, gives a blow of 60 or 80 pounds. It is evi-

*Assistant Inspecting Engineer, Universal Portland Cement Company, Chicago, Ill.

dent that with this method the operation of manufacturing tile can easily be duplicated time and time again, thus insuring their uniform quality.

A more or less satisfactory substitute for machine tamping is found in the pneumatic rammer which, although it will always strike the same blow, has the objection that the concrete must necessarily be rammed into position in layers.

The third division embraces tile which are made by the poured process, or with a concrete of such consistency that no tamping is required, but the concrete is rather jarred or churned into place. This method is proving quite satisfactory where a particularly dense concrete is required for draining alkaline soils or for the manufacture of sewer pipe.

It is not the object of this paper to fix or endeavor to calculate the maximum or minimum costs per thousand tile, but rather to indicate a method of procedure which will place the manufacturer in a position to know definitely what his tile cost him, as well as the distribution of cost over the different headings. It is to be regretted that the manufacturers of concrete tile machines are inclined to paint a more brilliant horizon for the prospective tile manufacturers than is warranted by actual practice, and often omit important items of cost such as interest on the investment, depreciation on the plant, renewals of machinery parts and the repairs on the building and machinery. The manufacturer also is inclined to neglect these details and consequently is oftentimes at a loss to determine why his plant does not pay better.

Since the methods of keeping costs can be equally as well illustrated with one method of manufacture as another, the cost data will be confined to tile of small diameter, 4 to 12 ins., as made with a rotating packer.

After studying the different methods generally employed for keeping cost data it was found that the card system was in all probability the most practical. By this method, space is saved and the bookkeeping reduced to a minimum. It will be necessary to use two styles of cards, Figs. 1 and 2, one for the daily record about 3 x 5 ins. in size and the other for cost and stock, preferably about 5 x 8 ins.

The Daily Report Card is to be made out by the foreman and each size of tile should be filled in showing the time required as

well as the cement used for each size. The cards are perforated so that they can be hung on a nail in the factory. Unfortunately, such a record is not generally kept by the tile manufacturer, consequently, when several sizes of tile are made on the same day it is impossible to make any proportional division of cost. This record is turned in at the close of each day and the different items transferred to the large cards under the various sizes, after which they are filed in a separate drawer, marked "Day" or "Daily Record." The tile per sack is then determined for each size by

DAILY REPORT. DATE *6/21/09*

SIZE.	NUMBER.	SACKS CEMENT.	HOURS.	HOURS LABOR.	REMARKS.
8"	*2,400*	*92*	*10*	*100*	*New packer head.*

FIG. 1.—DAILY REPORT CARD.

dividing the number of tile made by the sacks of cement used. From the curve, Fig. 3, the mixture is then obtained and multiplying the sacks of cement used by the proportion gives the cubic feet of sand.

The curve showing the tile per sack and the mixture has been figured on the assumption that the amount of cement in a tile can be determined from its weight, if the mixture is known. For instance, a tile weighing 20 lbs. made with a 1 : 4 mixture would contain an amount of cement equal to 1/5 of its weight, or 4 lbs. To find the tile per sack it is only necessary to divide the weight of a sack of cement, approximately 94 lbs., by 4,

8″ TILE

Day.	No. Tile.	Sacks Cement.	Tile Per Sk.	Mix.	Am't Sand.	Cost Cem.	Cost Sand.	Cost Labor.	Cost Fuel, &c.	Total.	Stock.		
											Forw'd 5,000.	Sales.	On Hand.
6/21/09	2,400	92	26.1	1:4	368	$34.50	$13.62	$20.00	$18.30	$86.42	7,400	1,000	6,400

FIG. 2.—COST AND STOCK CARD.

which gives 23½ tile per sack. In calculating the tables and plotting the resulting curves the average weight as determined in twelve tile factories was taken.

To prove the truth of this assumption the drain tile plant

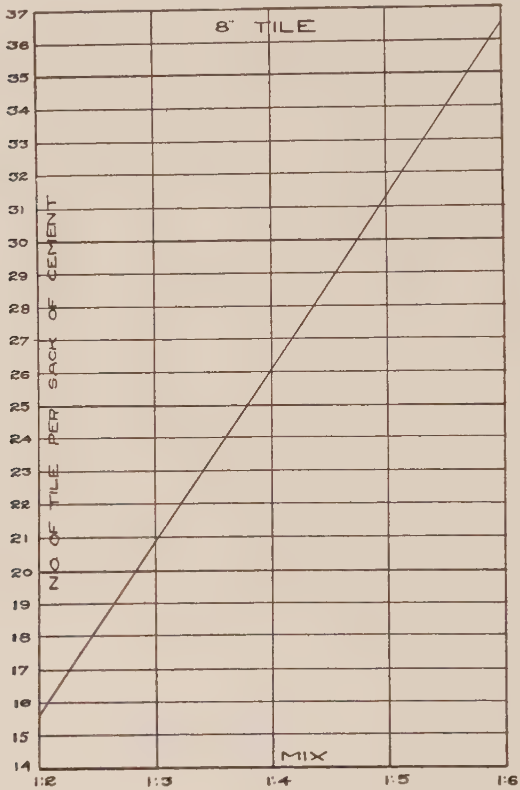

FIG. 3.—CURVE SHOWING NUMBER OF TILE PER SACK OF CEMENT FOR DIFFERENT PROPORTIONS OF MIXTURE.

of Griffin and Todd at Shabonna, Ill., was operated for about three weeks on all sizes of tile from 4 to 12 ins. inclusive, and with mixtures of cement and torpedo sand varying from 1 : 2 to 1 : 6. The materials were accurately measured in one sack batches and after adding the water and mixing thoroughly were run through the machine and the number of tile made noted. The

machine was then cleaned and a new batch put up in a similar manner. The actual test and theoretical calculation checked very closely and furnish a set of curves which should be of great value to the manufacturer of concrete drain tile.

After the amount of material has been determined the cost should be added on the large cards. From a curve, Fig. 4, it will be possible to determine immediately the cost of sand. The cost of cement, being a variable, must be figured for each entry.

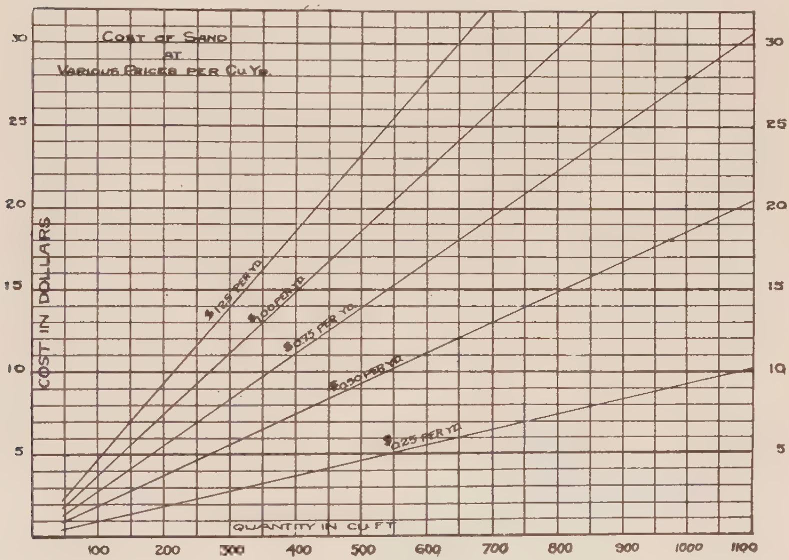

FIG. 4.—COST OF SAND AT VARIOUS PRICES PER CUBIC YARD.

The labor is calculated by multiplying the hours by the rate per hour.

The next column will include the interest, power, depreciation, etc., and must be proportioned to the size of tile. For instance, if the daily cost for these items was \$9.00 and the average number of tile made per day of a certain size was 3,000, the charge per 1,000 would be \$3.00. If, however, the plant was working on tile of which the plant produced only 1,500 per day the added cost would be double the other, or \$6.00 per 1,000.

The several items of sand, cement, etc., when added together give the total cost for the total number of tile of one size made on a certain day. The cost per 1,000 can be obtained by dividing the total cost by the number of thousand tile made.

The next division on the large card is intended to be a perpetual inventory of stock on hand. At the top under "Forward" should be placed the total from the last card filed. To that number is added the day's production. After subtracting the sales for the day the last column should indicate the stock on hand.

To illustrate the manner of keeping the record a case has been taken of a day's run of 2,400 8-in. tile using 92 sacks of cement. Dividing 2,400 by 92 gives 26 tile per sack. By referring to the curve, Fig. 3, the mixture is found to be 1 : 4. Multiplying 92 by 4 gives 368 cu. ft. of sand used. If this costs $1.00 per yd. the sand curve, Fig. 4, shows the total to be $13.60. Ninety-two sacks of cement at $1.50 per barrel will equal $34.50. The labor is obtained generally by multiplying the rate per hour by the number of hours. One hundred hours labor at 20 cts. per hour equals $20.00.

The next item is by far the most interesting and is the one hardest to estimate. In the particular case cited it is based on a plant and equipment costing $5,000, and operating 160 days in the year. The power is assumed to cost $1.50 per day and the foreman paid at the rate of $25.00 per week for the entire year. In a plant of this kind the depreciation must be included and is estimated at 10 per cent., while interest on the investment is taken at 6 per cent.

Plant repairs, insurance and taxes are taken from the sheet of an actual plant at $600; foreman at $25.00 per week or $1,300 per year. Operation 160 days, therefore, daily foreman expense is $8.00.

Interest on $5,000.00 at 6 per cent.	$300.00
Depreciation at 10 per cent.	500.00
Repairs, insurance, etc.	600.00
	$1,400.00

Expense per day, $8.70.

Adding the foreman cost increases the expense to $16.70,

and the power to $18.30. Added to the cost of the cement, sand and labor, makes the total cost for the manufacture of 2,400 8-in. cement tile $86.42. Dividing this by the number of thousand made, viz., 2.4 gives $34.35 as the cost per 1,000.

This same reasoning has been continued throughout the various sizes with a 1:4 mixture assuming that 10 men work continually and that the plant sustains a breakage loss of 3 per cent. on tile of all sizes. The same assumptions are made as before regarding investment, interest, power, etc.

Average daily production: 4 ins., 2,900; 5 ins., 3,000; 6 ins., 3,000; 7 ins., 2,500; 8 ins., 2,400; 10 ins., 1,800; 12 ins, 1,450.

MATERIAL COST PER 1,000 TILE.

Tile Diameter. Inches.	Cement. Bags.	Sand. Cubic Yards.	Cost.		
			Cement.	Sand.	Total.
4	3.25	1.44	$4.87	$1.44	$6.31
5	4.55	2.01	6.82	2.01	8.83
6	5.95	2.64	8.90	2.64	11.54
7	7.59	3.37	11.40	3.37	14.77
8	9.60	4.27	14.40	4.27	18.67
10	13.40	5.96	20.10	5.96	26.06
12	19.40	8.63	29.10	8.63	37.73

FIXED COST PER 1,000 TILE.

Size. Inches.	Production.	Foreman.	Interest, etc.	Power.	Total.
4	2,900	$2.76	$3.02	$0.52	$6.30
5	3,000	2.66	2.92	.50	6.08
6	3,000	2.66	2.92	.50	6.08
7	2,500	3.20	3.50	.60	7.30
8	2,400	3.34	3.65	.63	7.62
10	1,800	5.45	4.86	.84	10.15
12	1,450	5.50	6.04	1.04	12.58

LABOR COST PER 1,000 TILE.

Ten Men at Work Continually.

Size. Inches.	Cost.
4	$6.90
5	6.70
6	6.70
7	8.00
8	8.35
10	11.10
12	13.80

SUMMARY.

Size. Inches.	Labor.	Material.	Fixed Charges.	Total Cost.	
				Net.	Adding for Culls 3%.
4	$6.90	$6.31	$6.30	$19.51	$20.10
5	6.70	8.83	6.08	21.61	22.25
6	6.70	11.54	6.08	24.32	25.00
7	8.00	14.77	7.30	30.07	30.90
8	8.35	18.67	7.62	34.64	35.70
10	11.10	26.06	10.15	47.31	48.70
12	13.80	37.73	12.58	64.11	66.00

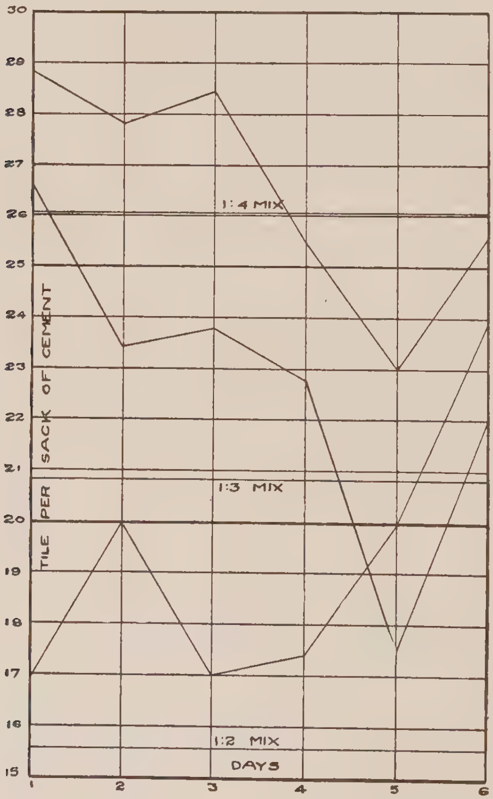

FIG. 5.—VARIATION IN MECHANICAL PROPORTIONER SET FOR 1:4 MIXTURE. 8 IN. TILE.

It is probable that these results do not agree with those found in actual practice because of the variation in some of the items such as number of men, daily production, and plant investment. It nevertheless shows a method of getting at the cost of tile to the manufacturer.

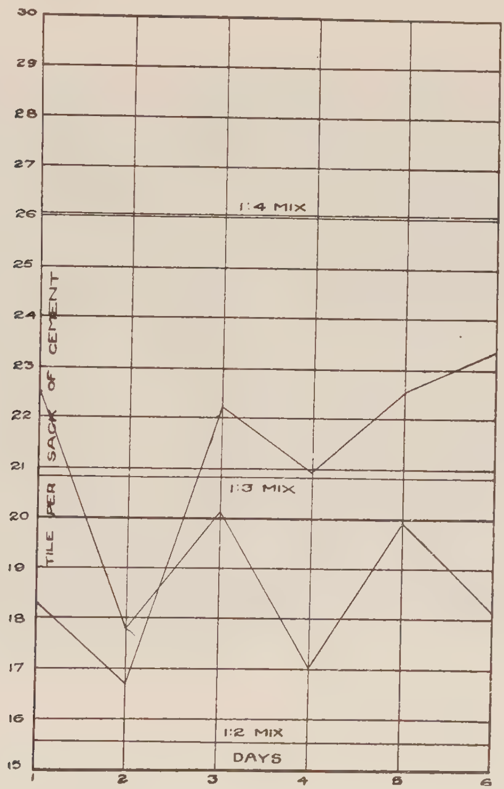

FIG. 6.—VARIATION IN MECHANICAL PROPORTIONER SET FOR 1:3 MIXTURE. 8 IN. TILE.

In an independent investigation of the drain tile question it was disclosed that it is oftentimes the custom to employ mechanical methods for the proportioning of the materials. The manufacturers thought that such a method was satisfactory and that after once setting the proportioner it would continue to grind

out the proper relative quantities of cement and sand. Figs. 5 and 6 show very plainly the result.

Fig. 5 shows actual runs from day to day on 8 in. tile, the manufacturer supposing he was obtaining a 1:4 mix. Fig. 6 shows the results of an endeavor to obtain a 1:3 mixture on tile of the same size. If the plants are operated as they should, and as they would if properly proportioning the materials, the zigzag

FIG. 7.—CEMENT TILE WHICH SHOWED A 25 PER CENT. INCREASE IN STRENGTH AFTER SERVICE FOR TWO YEARS.

lines would straighten themselves out and coincide approximately with those marked 1:3 and 1:4. Since the quality of the output of a plant is judged by the quality of the poorest product, it is necessary that tile manufacturers should investigate methods for uniformly proportioning their materials.

Concrete drain tile possess many advantages, the most important of which being their ability to resist frost action. This is probably due to the fact that in their manufacture the material does not form itself into layers paralleling the surfaces. The

pores or voids are so evenly distributed that the expansion of frozen water contained has no disintegrating effect on the tile wall.

Five cement tile, Fig. 7, showed after two years of service a 25 per cent. increase in strength over the average run of tile taken directly from the yard and made by the same plant.

Five pieces of cement pipe at South Bend, Indiana, are shown in Fig. 8, which were made of Portland cement. They were placed as a culvert near the farm of Jacob Young in 1883, but were taken up in 1889 when the road was regraded. Since

FIG. 8.—CEMENT PIPE LAID IN 1883, TAKEN UP IN 1889, AND FOUND IN EXCELLENT CONDITION IN 1909 AT SIDE OF ROAD.

that time they have lain at the side of the road until 1909, when three of them were tested and found to be in excellent condition.

Uniformity in shape and square ends are decided advantages in favor of cement tile. Fig. 9 shows the end of a cement tile compared with that of one made from another material and which had been warped out of shape in one of the processes of its manufacture. It can easily be seen that if two such tile are placed end to end the effective area is decreased and because of the increased friction the capacity of the drain is lessened appreciably. Considerable difficulty is experienced in laying tile by machine where all are not circular and true. Oftentimes it is

necessary to stop the machine in order to extricate a misshapen tile which has stuck and clogged in the chute. Uniformity in shape is also greatly appreciated by the ditcher, some saying that they can lay twice as many cement tile as they can others which are twisted and warped.

To quote from Professor Kirsch, of the Technical High School at Vienna: "The conclusions to be drawn from practical experience perfectly correspond with what might reasonably be expected from Portland cement concrete by a person familiar with its physical properties. Portland cement concrete obtains its maximum durability if it is kept in a moist atmosphere for a

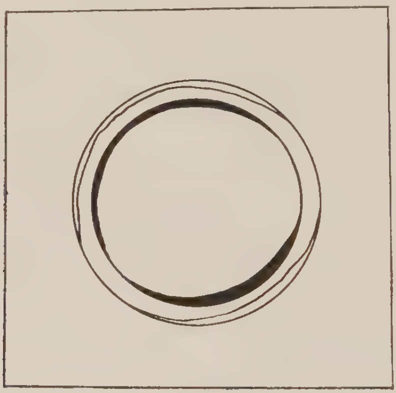

FIG. 9.

short period after being made and if it is afterwards permanently immersed in water." This is identically the same treatment to which concrete drain pipes or sewer pipes are submitted after being made. They are permanently kept moist. The durability is thereby not lessened in the least in the long run; on the contrary, the excellent physical properties of these concrete pipes are continuously improved by it.

The most satisfactory proof of the many advantages of concrete tile, however, is to be found not only in their increasing number of consumers, but in the number of people who after having bought, tried and tested them, are willing and anxious to buy more.

DISCUSSION.

Mr. J. H. Libberton.—We tested tile by several methods and operated a plant in order to test steam cured tile, but as yet have not determined anything definite regarding steam curing. I have heard many different solutions offered for the steam curing problem and although it is undoubtedly true that steam curing hastens the hardening of the cement, the rate of increase is uncertain. **Mr. Libberton.**

Some work has been done using steam at a temperature of 200 or 212 deg. In our work with the perforated pipe, we admitted steam at a pressure of 80 lbs., and were able to bring the temperature to almost any point desired. We aimed to keep it at about 130 deg., but in the majority of tile plants it is often found difficult to keep the temperature at that point and still maintain the moist atmosphere which is so essential to proper curing.

Mr. B. Schubert.—What is the average strength of tile? **Mr. Schubert.**

Mr. Libberton.—The average strength of cement tile is about 10,000 lbs., depending, however, on the method used. The tests were all made on 8 in. tile, so that the results are comparative. **Mr. Libberton.**

Mr. Ernest McCullough.—Was the method of imbedding the tile for test the result of experiments to determine the best method? **Mr. McCullough.**

Mr. Libberton.—The method used is one, which has, as far as I know, never been used before. There are many different styles of loading tile. One used at the University of Illinois for testing pipe provides a pile of sand all the way around to bring pressure to bear on the pipes. A similar method is used at Ames, Iowa, except that the tile is imbedded in sand, 25 per cent. above and below, using a wooden saddle to hold the sand and a cloth sack to keep it from leaking. Another method recommended by the University of Illinois is crushing against two flat plates above and below. The objection to this method for concrete tile **Mr. Libberton.**

Mr. Libberton. is, that it causes excessive pressure on the corrugations. A method recommended and used, I believe, in the City of Brooklyn for a time, was a so-called three point method, in which the tile were supported on two strips at an angle of 60 deg. on the bottom, and the load applied on an upper strip along the center of the tile. With the three point method it would be necessary, of course, to imbed the tile in plaster so as to obtain a uniform bearing, which could readily be done.

The object of the investigation was to determine whether or not the manufacturer of cement tile was getting a uniform product, and to furnish him with some reliable data on the subject.

Mr. Gilbreth. MR. F. B. GILBRETH.—I would like to hear as to the proportioning and grading of the relative sizes and the coarseness of the materials with reference to the thickness of the shell of the pipe.

Mr. Libberton. MR. LIBBERTON.—The size of the aggregate is determined by the thickness of the tile, and the maximum size should not exceed one-half the thickness of the tile wall.

Mr. Bartlett. MR. J. L. BARTLETT.—The City Engineer of Greeley, Colorado, has written a specification for concrete sewer pipe for submission to the Council in which he recommends a test on a 12 in. pipe to have a 10 in. sand base, and a bearing on the top of 1 in. in width running the length of the pipe, which shall show a strength of 1,000 lbs. per lin. ft. before failure. In addition he wished to incorporate the requirement of a 10-lb. hydraulic pressure before any seepage should be shown. I want to ask whether in the light of experiments and tests made either of those conditions would seem unreasonable and difficult to meet. Large tile are not specified. Up to the present time the tile are made untamped of a 1 : 3 mixture, with bank gravel.

Mr. Libberton. MR. LIBBERTON.—I think that serious difficulty would be experienced in obtaining an untamped tile to show no seepage at 10 lbs. pressure. With poured tile, however, I think the requirement would be reasonable. We have made tests on poured concrete tile of a wall thickness of 2½ to 3 ins., which showed an absorption of only about 3½ per cent., which is as low as found in any competitive material.

As far as the question of seepage is concerned and the ability of tile to resist a pressure of 10 lbs., it is a question whether or not sewer pipe is called on to resist such a pressure. The pressure of 10 lbs. would approximate about 23 ft. of head, and it is doubtful if that head is often experienced. Of course, if it is, such a clause might be reasonable. It is, however, absolutely necessary for sewerage purposes that the tile shall be as impermeable as possible, and therefore the method of manufacture which gives the minimum absorption, should be the one adopted. **Mr. Libberton.**

The President.—The Chair thinks that the question of sewer tile is one that needs development in this country. In Europe the practice of making tile for sewerage purposes is quite different. Most of the tile are molded under pressure, with wetter mixtures, and the result is a density in the tile, which has a ring. As Mr. Libberton has said, the necessity of having impervious tile, especially for sewer work, is the main essential. The mere fact that it is able to resist a hydraulic pressure is not essential, because the sewer pipe is not, except under extreme conditions, called on to withstand such a pressure. **The President.**

ESSENTIALS IN CEMENT HOLLOW BLOCK MANUFACTURE.

By Ernest B. McCready.*

So much has been said and written concerning concrete blocks that it seems like thankless repetition, almost to touch upon the subject at all. And yet, in spite of all the full and explicit instructions in the literature, and all the warnings that have been sounded, notwithstanding the specifications which have been formulated, we, whose business it is to test and inspect materials and determine the sources of trouble and reasons for failure, know that the same mistakes are being repeated day after day and year after year. This is in part due to the rapid growth of the business and the enlistment of new and inexperienced forces; but even more than this is responsible. The universal desire for the greatest gain with the smallest outlay.

The question has been asked, "What are the essentials in the manufacture of concrete blocks?" The answer is simple, there are but two—good materials and good workmanship. To secure both, or either of these, is not so simple. As regards materials, it is difficult, from the standpoint of known failures, to say which is the more important, the cement or the aggregate. Too many manufacturers seem to think that the cement is the only important consideration and that any fine mineral material will do for the aggregate; while others who are very careful in the selection of the aggregate will use any brand of cement, if the price is right and if, perchance, it has "been in the market for more than three or five years," as the case may be, without any intelligent investigation or test as to its fitness for the purpose; and then, perhaps, fail wholly to realize that the color which condemns the blocks is due entirely to the cement.

Very few block manufacturers have the necessary equipment for satisfactory and complete tests of cement, and fewer still

* General Manager, Lehigh Valley Testing Laboratory, Allentown, Pa.

have the experience requisite for intelligent testing and interpretation of the tests. Most manufacturers will find it a good investment to send at least an occasional sample of the cement to a reputable testing laboratory, if only for the purpose of keeping check on the quality of the material. When sending such samples it is well to state the purpose for which the cement is to be used and to ask specifically for the information desired. A general report may overlook just the particular information wanted.

There are two simple tests that can and should be made on every new lot of cement before it is used, and especially in warm weather. A handful of the cement should be mixed with water to a smooth, rather stiff paste and made into a flat cake or pat about one-half inch in thickness, on a piece of glass. This should be watched until it sets, or at least, until the required minimum time has elapsed. It should be easily impressed with the soft end of the finger at the end of 30 minutes and should not become so hard as not to be easily indented with the nail at the end of 2 hours. The pat should be kept in a cigar box, covered with a damp cloth, or in some similar way be protected from rapidly drying out. Dangerous quick-setting can readily be detected in this way.

After it is thoroughly hardened (or, preferably, the next morning) the same pat should be placed in a pan or can of water, and the water boiled for at least 5 hours. The pat should then be hard and sound and ring when struck, like a piece of stone. If it is easily broken or soft and watersoaked, or if it is cracked or checked, swelled or disintegrated, the cement is proportionately unsound, and it would be well to have a sample of that lot submitted to an experienced cement tester before using it. Although some have inveighed against it, the fact remains that from the consumer's standpoint, certainly the boiling test for soundness is of great value, simply as a matter of insurance. While a cement that fails to pass the boiling test may never cause concrete made from it to actually disintegrate, yet if it is used before it has seasoned long enough to correct this deficiency, the force which causes failure in the accelerated or boiling test will surely have its effect in reducing the ultimate strength of the concrete.

It is not the purpose of this paper to discuss at length the subject of cement. The ultimate strength as well as the rate of hardening is of great importance to the block manufacturer, as is also the fineness of the cement, or its sand-carrying capacity. The cement is used for its strength, primarily, and we want all of this commodity we can get.

In considering the aggregate, the first essential is that it shall not be too fine. Fine material is probably the cause of more trouble than all other sources combined, at least this has been the writer's experience. Some men read that "a little clay or other fine material is an advantage and adds to the strength," and then are greatly surprised when told that the putty-like face and the checking and crazing of the surface of the blocks is due to the fact that perhaps 30 per cent. of crushed stone passes the 100-mesh sieve. In one case noted recently, material was being used for concrete, in which more than 50 per cent. of that portion which was finer than 10-mesh passed through the 100-mesh sieve.

In most cases where there is a serious deficiency in the composition of the aggregate, it is the lack of coarse material. Many use sand alone, others use sand and crushed stone, all of which will pass a 4-mesh or even a 6-mesh sieve, and from which none of the dust has been removed. As an example of the other extreme, may be mentioned one of a lot of 6 blocks from different makers submitted for test by a prospective builder. This was a faced block, with face colored and made of fine sand. The body of the block was made of very coarse material, little of which seemingly would have passed a 10-mesh sieve. This block was so porous that a continuous stream of water, ¼ in. in diameter, allowed to fall gently on the block, did not run over the edges but passed away through the block.

It is not essential that sand should be washed, provided it contains no more than 5 per cent. (or at the most, 10 per cent. if the sand is well graded) of fine material passing the 100-mesh sieve. This finest material should be fine sand or clean clay or some added material as hydrated lime, but *not* surface soil. Blocks of the best color and surface texture are made from washed sand and gravel or from clean crushed stone.

Manufacturers using too fine a material are often, as a consequence, mislead in proportioning the mixture of cement and aggregate. They have been told that 1:4 or 1:5 makes a good, rich mixture; and they forget or do not know that the material recommended for these proportions contained gravel up to ½ or ¾ in. in size. When their blocks made of fine sand in the same proportion fail to withstand 1,000 lbs. per sq. in. at 30 days, they blame the cement. They should remember that 1:4 of graded gravel really means 1:2 of the finer portion, or even richer.

The strength of the block also depends upon the strength of the material used as aggregate. A block made of crushed slag, in whole or in part, will not be as strong as one made of crushed limestone under the same conditions. For the same reason there is little advantage in mixing crushed trap rock with crushed limestone, on the principle that a chain is no stronger than its weakest link.

Finally, the value of the best materials may be largely nullified by wrong methods of manufacture. Explicit directions and descriptions of the best practice are available for all who care for them. It is desirable, always, whatever we may do in our efforts to economize to remember these three points,—that it is impossible to turn out the best block unless: (1) The materials are thoroughly mixed, both in the dry state and after the addition of water; (2) The material is properly placed in the mold; (3) The blocks are carefully and sufficiently seasoned.

The merits of machine mixing are acknowledged, and this method is always to be preferred wherever at all possible. Much depends upon the care with which the molds are filled and tamped, especially with machine made blocks; and it should be remembered that the mixture should be as wet as possible, so long as it does not seriously interfere with handling the blocks. During the seasoning blocks should never be allowed to dry out, for if the block once becomes thoroughly dry on the inside or if the amount of water added in the mixing is insufficient for the crystallization of the cement, the interruption in the hardening and the consequent loss in strength can never be wholly remedied.

INSTALLATION AND OPERATION OF A STEAM CURING PLANT.

By F. S. Phipps.*

The installation of a steam curing plant and its satisfactory operation covers a large and important subject, and it will be endeavored to present the same in such a manner as to enable a block manufacturer to intelligently make use of the advantages of steam curing.

The steam curing of cement blocks was originally applied to the semi-dry block by placing the block in the steam room immediately after it is made and giving it steam. Within one or two hours the block becomes filled with moisture and the heat from the steam causes the cement to set long before the block could be sprinkled or sprayed. It has been found more satisfactory to leave a block made by the wet process stand for 12 to 20 hours before applying the steam. After the lapse of that time the block hardens very fast and takes on a lighter color, impossible to obtain otherwise.

It will be assumed that the plant is equipped with three or four deck cars for handling the cement blocks. Racks could be used in the steam rooms and the blocks carried to and placed on them by hand. This will be found very expensive, as a great deal of time is required to fill the steam room and empty it. Again, there will be a great deal more breakage. The doors should be as near as possible to the block machine, as the further it is necessary to move the green blocks the more liable they are to break. After the blocks are cured, they can be run any distance without danger of damage. This is one point that has been found important in laying out a new plant.

The size of the steam room depends on the dimensions of the blocks to be made and the contemplated output of the plant. Under no circumstances should the steam room be so large that it would require more than one-half a day to make the product

* Manager, Central Stone Company, St. Joseph, Mo.

necessary to fill it. As a matter of fact it has been found advantageous to use such a size as can be filled within 2 or 2½ hours.

TYPES OF STEAM ROOMS.

In general there are three types of steam rooms classified according to the method of construction. (1) Wooden walls lined on the inside with galvanized iron sheeting, (2) wooden walls lathed and plastered on the inside, (3) walls of concrete blocks untreated on the inside.

1. The walls can be made of wooden flooring nailed to the outside of 2 x 4-in. or 2 x 6-in. posts. The inside is lined either with roofing paper or galvanized iron sheeting. This will give a very good steam room for a year or so, but in the course of time the iron will rust and the condensed steam will carry the rust with it in dripping on the blocks, discoloring the same. The ceiling can be made either arched or flat, lined with galvanized iron. An arched ceiling is always to be preferred as the condensed steam is not so liable to drip, but will rather run down the sides. The ceiling should just be high enough to clear the cars so that there will be no dead space above the blocks.

This type of steam room has been used to some extent for the past 3 years, giving fair satisfaction for a cheap apparatus and one that can be built and removed quickly. If located inside of the factory the back wall can be omitted by using the wall of the building. The partition walls can consist of galvanized iron nailed to 2 x 4-in. posts.

2. In the second type the galvanized iron lining is replaced by laths and plaster. Steel laths are more satisfactory than wooden laths. The ceiling should, without doubt, be arched.

In this type there is no danger of the rust being carried by the condensed steam to the blocks, but continuous use has shown the same unsatisfactory by reason of the expansion and contraction of the plaster due to the large range of temperature. The expansion causes cracks in the wall and necessitates the use of a larger quantity of steam. This extra steam will not amount to very much at one time, but in the course of a year or so the expense would be quite noticeable.

These two types of steam rooms, being of temporary rather

than permanent construction, are recommended only for use in plants not permanently located, that is, if a short term lease can only be secured, otherwise the expense of installation and removal will be too great.

3. The third type is one which I have found satisfactory in every way, and can be built of the product of the plant. The

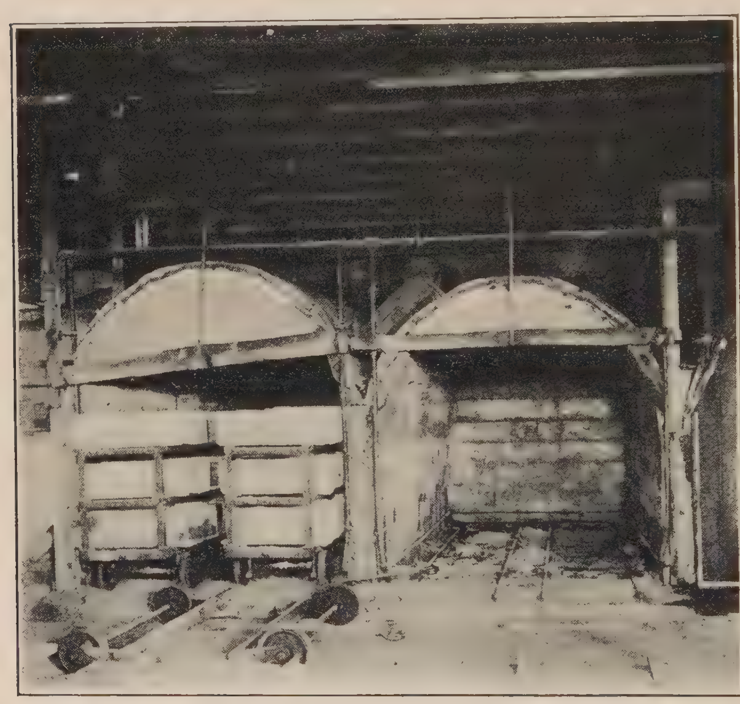

FIG. 1.—CONCRETE BLOCK STEAM ROOMS.

description will cover steam rooms which have been in successful use for some time (see Fig. 1).

The inside dimensions of the room are 15 ft. long and 6½ ft. wide. The side and rear walls are of 12-in. smooth blocks. The ceiling is arched, giving a maximum height of 7 ft. 3 in.; the arch leaving the side walls about 45 ins. from the floor. The arches are 6 ins. thick and made of a gravel concrete reinforced with ½-in. corrugated bars running lengthwise about 1 ft. apart. The division wall between steam rooms is 12 ins. thick and carries two

arches. In order to add a new kiln it is only necessary to construct new side and rear walls and the arch.

The track is laid on old railroad ties 2 ft. apart, cut to fit, giving a solid and substantial track. The floor is of concrete so that it can be kept clean. It is found best to have cement floors around the tracks and the block machines so that all the material can be thoroughly cleaned up and used again, not wasted, as is the case when a cinder floor is used.

The front of the steam room is open, being covered with heavy canvas during the steaming. The canvas is attached to a 2-in. plank, 12 ins. wide, fastened to the arch and side walls by means of ½-in. bolts set in the concrete during construction. The canvas is cut on a circle to fit the arch and fastened by means of wooden strips, allowing the canvas to roll up sufficiently high to clear the cars loaded with blocks. When the steam room is filled the canvas is rolled down and fastened by means of two or three laths, the weight of the roller at the bottom holding it snugly to the floor. The canvas curtain also acts as a condenser and reduces the temperature in the steam room.

There should be a ventilator in the roof of the plant immediately in front of the steam room, so as to carry off the steam coming out through the curtain. This is especially necessary in the winter so that the steam will not collect on the ceiling of the shop, causing it to be damp and to prevent the condensed steam from dripping on the work.

The boiler we are using is of 25 horse-power, which is sufficient for 12 steam rooms of the size mentioned. It is a horizontal boiler properly installed and equipped with all the necessary appliances and carries 80 lbs. of steam. It is very important to have a good boiler, to have it tested, and to carry a full equipment such as would be required if 60 to 80 lbs. of steam were carried continuously. Twice a week the steam pressure is run up to 15 or 20 lbs. and the boiler and flues blown out with steam, eliminating all chances of accident such as often occur to old boilers. A good boiler properly installed and covered with asbestos will save one-half of the fuel, if properly run. A good second-hand boiler can be bought very reasonably, but it should be thoroughly overhauled and supplied with new fittings and new pipe so that the joints will not leak.

The steam pipes are of 3-in. pipe running about 18 ins. above the top of the arch, as can be seen from the illustration. By the means of a reducing T a 1-in. pipe is run down on each side of the kiln to within 1 ft. of the floor. The pipe then runs horizontally to the rear of the kiln, being there closed with a cap. On the upper side of this pipe ¼-in. holes are drilled every 15 ins. to permit the steam to escape. About 3 ft. down from the 3-in. pipe a valve is inserted in the 1-in. pipe to control the steam supply.

The track in the kiln will depend on the size of the cars. We use a 24-in. gauge with a 7 ft. car which gives 4 cars to an oven. It is intended to make one of the ovens wider than the others so as to permit the placing of large work in the center of the kiln and giving room for its proper handling. The transfer track should be immediately in front of the steam room. The transfer car is very advantageous in removing the product to any part of the plant or storage yard. Fig. 2 shows a general view of the plant.

The steam room referred to permits the use of 4 three deck cars, which means about 100 or 125 blocks. 32 in. pallets are used as blocks 4, 6, 8, 10 and 12 ins. wide and 9 ins. high are made. The pallets can be made of wood if the cleats are properly fastened and wide boards are ripped half way through on the under side to prevent warping when they expand, due to the dampness. Wooden pallets have proven very satisfactory and can be made of any ordinary pine lumber, although white pine is better but more expensive. Pallets of hard pine properly cleated and nailed and stored in straight piles when not in use, will give little trouble. Iron pallets are satisfactory if they be galvanized, as there again is the danger from rust.

Any type of block car is satisfactory, but the iron above the wheels should be galvanized so that it will not rust. There has not been much trouble from rust, but it generally happens that trouble occurs with some special block.

COST OF INSTALLING A STEAM CURING PLANT.

The cost of installing steam curing rooms will, of course, vary with the size. One of the size described, 6½ x 15 ft. by 7 ft. 3 ins. in height, with an arched ceiling, will cost from $50 to

FIG. 2.—GENERAL VIEW OF CONCRETE BLOCK PLANT.

$60, exclusive of the forms. The forms for the arches will cost about $20 to $25 including the lumber and labor. These forms can be stored and used for additional steam rooms when desired. After the first one is constructed one side wall will be saved on additional rooms. If about four steam rooms were to be built at one time, their cost would be about $40 each. These values do not include profit which should be added in case the work is done for someone else.

The piping, including the overhead pipe will cost about $12 per steam room.

A 25 horse-power boiler, including smoke stack, fittings and setting up should not cost more than $225. Cement brick for the foundation of the boiler can be made right in the plant; blocks can be used if preferred. This work can all be done by the block manufacturer himself, at least, we have always installed our own boilers and steam rooms without hiring expensive labor.

Taking the above figures, the total cost of a steam curing plant having four rooms, and a 25 horse-power boiler would be about $400, exclusive of the track and cars. The concrete block room used in connection with a horizontal boiler will require about one-half of the fuel of one of galvanized iron or plaster with an upright boiler. It would not take long to save the difference in the cost between the two.

The small amount of coal necessary to run a boiler under normal conditions is quite surprising. 1,000 lbs. of coal will cure 3 to 5 rooms of blocks. We have to pay $2.25 per ton for our coal, and even figuring $2.50 per ton, 5 rooms of blocks can be cured for $1.25, making the cost per room $.25. The wages of a man for sprinkling and taking care of the blocks would be a great deal more. Of course, the boiler is to be fired and filled with water, but this will not require a fireman all the time. He can do other work, and if a man is employed in a plant at night, he can unload the cured blocks and have the cars ready for use in the morning. In this way the expense of firing the boiler and the cost of the coal will not exceed the wages of a man to take care of the blocks under the sprinkling or spraying process, so with steam curing there is the advantage of turning out the blocks in from 30 to 48 hours. There is no doubt that a better block can be turned out

in this way than in from 7 to 14 days under the old process, and the cost is certainly not greater. Most of the blocks can be used in from 10 to 12 days sooner, giving a greater capacity for the plant and the storage yard, as the blocks do not have to be piled up for any length of time.

Operation of a Steam Curing Plant.

A cement block to be well made must have the proper amount of cement and the proper amount of moisture, and must be well tamped whether steaming, sprinkling, spraying or immersing is used in the process of curing. It is not possible by means of steam curing to make a good block from a 1 : 6 mixture where it ought to be 1 : 3 or 1 : 4. A poorly proportioned block with steam curing will make a poor block just the same as under any other process of curing. After the blocks are made they are set on the cars and immediately transferred to the steam room. In extremely hot weather the blocks should not be allowed to set longer than 2 to 2½ hours, and the steam room should be of such size and so arranged that they will be filled in this time. In extremely hot weather a canvas curtain should be dropped after each car as it goes in. The canvas curtain should be closed and tacked as soon as the room is filled, and it depends entirely on the weather and the setting of the cement as to how soon the steam should be turned on. The only way is to use good judgment, noting the conditions at the time. If the weather is hot and dry, the cement will set quickly and the steam must be turned on immediately on closing the steam room. The steam should be turned on slowly and gradually increased to the capacity of the pipes. If the steam is turned on too fast, the blocks will become mushy and mash. In some cases it has been found necessary to spray the blocks in order to reduce the heat and condense the steam faster. In all cases the water should stand high in the boiler and the steam should leave the boiler as moist as at all possible, as dry steam is not good for curing the blocks. The boiler should be carefully watched, so that the water will not get low and dry steam result. It is well known that sprinkling will wash some of the cement from the outside of the block, and the heat of the steam will cause the cement to set quickly and the moisture will

sink into a block. Even if one could cure a block by sprinkling as well as by steam the resulting product would not be as good, since the sprinkling process washes some of the cement from the surface. All blocks should be immediately taken to the steam room so that there will be no chance for them to dry out, as would be the case if they were set outside of the building where the sun or an air current could strike them.

The amount of fire in the boiler is regulated by the sound of the escaping steam. The steam gauge is never allowed to show a pressure above 3 lbs., and mostly no pressure at all. Our blocks under these conditions are cured and ready to be taken to the storage yard in from 24 to 36 hours. It is not to be understood that the blocks are as hard as they will get or completely cured, but the block will be every bit as good as one that has been cured for 7 to 14 days under the old process. It is well known that a block cured by sprinkling 24 hours often cannot be handled with safety.

In the case of the poured block it is not necesary to put it into the steam room until 12 to 20 hours after it is made. Steam curing of additional 12 to 20 hours is sufficient. If poured work, especially that with a troweled face, is immediately steamed, it will scale. If, however, the work stands for about 12 hours and is then treated for an additional 12 to 20 hours, the product is fit to handle and can be put directly into a building. It has been found necessary a good many times to remove poured work from the steam rooms, after 6 to 12 hours of steaming and the product has been found satisfactory.

It is believed that the above description of a steam curing plant will enable a block manufacturer to install steam rooms, but it is best in all cases to secure the services of an experienced man.

DISCUSSION.

Mr. A. C. Raymond.—My steam curing plant is located in Detroit and the steam rooms are made of my own blocks. The blocks come from the press in steel cars about 6 ft. long, which are the mold boxes, and stop directly in front of the opening into the steam room. No rack cars are used, no transfer cars. The blocks 32 ins. long, are taken on the pallets, one man at each end, and placed on racks laid upon sleepers, which have been placed on the floor in the bottom of the steam room first. We use a form of racks which we can pile up 4 or 5 tiers high. Our steam rooms are 17 ft. wide, 22 ft. long, and about 7½ or 8 ft. high, holding about 250 wall ft. We subject our blocks to steam only 24 hours in the coldest weather in the winter or warmest weather in the summer. We find 24 hours ample, except in the case of fine ornamental work, all of which we cure in the steam room 36 or 48 hours. This gives very fine and hard edges, especially with white silica sand and white cement. If the ornamental work is more than 5½ ft. in length or 20 ins. wide or 14 ins. thick, tamped by hand inside the kiln and the work is not moved until after it is steam cured, which gives a very fine texture and uniform color, very strong and hard. We have no broken blocks, because they are handled by men's hands. It is estimated that a saving of from $1,800 to $2,000 was effected by dispensing with rack cars, transfer cars, etc. Mr. Raymond.

The blocks are taken from the rear of the kiln directly into the yard and carried by hand to nearby piles or by flat cars running on tracks immediately in the rear of the kiln. Now as the business grows—we have a capacity now for 1,000 wall ft. a day—we will extend the tracks on which the steel mold cars run, farther and farther out, grouping the steam rooms on each side. We have some 360 or 370 ft. in depth of our lot and we can run that up to a capacity of 5,000 wall ft. a day if it is necessary.

Mr. Gilbreth. MR. F. B. GILBRETH.—Regarding the change of color of these blocks when they are in the steam, not the change of color on the exterior of the block, in case a block should be opened, how much cutting of the finished stone could be done by the usual stone cutting process with a hammer and chisel, without losing color?

Mr. Raymond. MR. RAYMOND.—We have made blocks faced with white silica sand and white cement and put on the facing 2 or 2½ ins. thick, cured them in steam and had them tested with pitching tools, and they will break as sharply and cleanly as Bedford limestone and make as handsome an appearance in the wall.

Mr. Gilbreth. MR. GILBRETH.—That is not quite the information I wish. I want to know about the color in the interior of the block. Mr. Phipps obtained a very much whiter block. I want to know if that color extends all the way through the block, and if it does not, how far?

Mr. Raymond. MR. RAYMOND.—When the blocks are being steamed they are of a dark color and look as though they had been rained upon. Just as soon as the curtains are lifted and the outer doors opened they begin to grow lighter in color. My experience does not agree with that of Mr. Phipps, that you can use almost any kind of ordinary gray cement and get uniform color. You will get the lightest color that the cement you use affords, when it is practically dry, and you will not get anything lighter than that unless hydrated lime or something of that sort is used, which will change slightly the color of the cement. We have tried to control the color a little, get a little difference in shade, by using a brand of cement that is of a lighter shade, some light yellow and some light gray and so on. But the difference in color between the very darkest form of gray cement and the lightest does not amount to very much. If we want light effects we get them by using light colored sand with light gray cement or white sand with pure white cement, or gray cement with white sand, or white cement with different colored sand, buff or white or grain chips, or marble and so on. Instead of using the mineral colors we try to produce colors by mixing different grades of material.

Mr. Watson. MR. CHARLES D. WATSON.—In steam curing the depth of

the color depends on the length of curing. In 24 hours there will be a layer of uniform color for probably ¼ in., in 48 hours it will be ½ in. thick. The inside of the block is not cured, being gradually cured afterwards.

MR. F. S. PHIPPS.—It has been my experience that the block is of the same color throughout. When the block is taken directly out of the oven it is wet inside; it has not yet dried out. After the block is 10 or 15 days old there is practically no difference in the color inside the block and outside. **Mr. Phipps.**

MR. DANA G. CHANDLER.—I have a steam curing plant and have discovered that by leaving a block in a short period, say 12 or 24 hours, we would have a far different color inside than you would have on the outside, but if you leave the block in 48 hours or more under low pressure steam and plenty of water, when seasoned and cured, it will be of a uniform color clear through. I cure the blocks with the exhaust from the engine, not live steam direct from the boiler, but run with high water and low pressure. We have tried this matter in a great many different ways and experimented, and I find it is the same with steam curing as it is with sprinkling. If you just simply give it a light spray, only slightly wet the block, and then put it out, you will not have a uniform color clear through. The material must have the same amount of water clear through in order to give the same color. **Mr. Chandler**

MR. PHIPPS.—It has been my experience that steam direct from the boiler, not using pressure for heating and having water high, is better than the exhaust of an engine. I have used the exhaust of an engine and did not have as good results as I have had with live steam. **Mr. Phipps.**

Of course, judgment is as necessary in steam curing as in any other line of business. A small 4 in. block will cure quicker than a block that is 12 ins. thick and solid. It takes more time to cure the latter than it does the small one. Whenever possible we would hold the blocks 30 to 48 hours, but once in a while we must take them out in 24 hours.

MR. J. L. BARTLETT.—I would like to ask if it is safe in extreme cold weather to take the blocks out in 24 hours and place them in the yard without danger of freezing or cracking? **Mr. Bartlett.**

The President.

THE PRESIDENT.—The question as to whether or not it was safe to take steam cured blocks out into a freezing temperature I think is one which can be answered in this way. Concrete which is not properly hardened is affected by frost, and concrete which is properly hardened is not affected by frost. So that if the concrete blocks are of proper density and not too porous, taking them out of the steam curing room into the open air, even where the temperature may be below zero, would not necessarily affect the blocks. It is the alternation of freezing and thawing that injures concrete which has not the requisite strength to resist it.

The question of the influence of steam curing on the discoloration of the surface is a point which the Chair would like to touch on. If there is a great deal of moisture and the blocks sweat considerably, there is a tendency to bring out of the cement certain hydrates which upon the drying of the block will give it a white color. As soon as the block, properly cured and quite hot, comes out into the air it dries out very rapidly, and this rapid drying out has a tendency to bring the moisture to the surface rapidly. I think it also has a tendency to bring up the lime salts which would make the block slightly white.

The remarks of Mr. Phipps, I think, were well taken, in that you cannot cure a bad block by steaming it. You have got to make a good block, and the whole function of steam curing is simply to accelerate the hardening. It will not change the texture of your block a particle, but it will enable you to handle the block in a much less time, if it is properly done.

Mr. McCullough.

MR. ERNEST MCCULLOUGH.—In regard to the effect on the color by the use of exhaust steam would not that be due in some small part, perhaps, to the amount of vaporized oil carried in the exhaust steam?

Mr. Phipps.

MR. PHIPPS.—Once I ruined a number of blocks by using exhaust steam. We had a 75 horse-power boiler and a 25 or 30 horse-power engine, which were entirely too large for the plant. The oil was turned on full force into the cylinder and ran day after day, giving a good deal of trouble. The blocks were all spotted with grease.

MR. CHANDLER.—I would say that as far as the oil is concerned we have not had the least bit of trouble. We are located in a small town of about 1,500 inhabitants and have sold over 60,000 blocks. All the oil we have noticed from the engine would come out through the pipe and lie on the ground, but we have never noticed a particle on our blocks, not even a greasy surface. Mr. Chandler.

MR. W. P. ANDERSON.—The manner of passing the steam into the curing rooms has not yet been clearly stated. The system that has been adopted in some cases is the placing of small water tanks on the bottom of the curing room, 12 or 24 ins. square, and tapping the steam pipes down into that water, and all the steam must go through it. Then there is a hot and wet steam, with no chance of getting a burned block. Some put the steam into the top of the steam room. I do not think that is very good. Others put it into the bottom, but it is practical to put it into a tank of water. The steam cannot get out of there without wetting everything that it goes up through. Mr. Anderson.

REPORT OF THE EXECUTIVE BOARD

FOR THE

YEAR ENDING DECEMBER 31, 1909.

Meetings.—The meetings of the Executive Board during the year have been reduced to the minimum of two full regular meetings in order to save expense and the details connected with the administration of Association affairs have been intrusted largely to the Executive Committee, acting in co-operation with the President, and its meetings have been more frequent.

Membership.—At the close of the 1909 Convention there appeared a total membership of 833. By January 1, 1910, the total membership amounted to 854. At this time, the Executive Board considered the Association sufficiently strong in membership to drop delinquent members that had been carried during the past year or two, and 260 were, in this manner, taken from the membership registration, some expense thereby being saved. From the close of the 1909 Convention to February 19, 1910, 204 new members were added, leaving a net live membership on this date of 777. Between February 19th and February 22d, 47 new members were added, making a total of 824, and if the usual gain is made during the Convention period this total should be considerably increased before the close of the present Convention. It must be noted that the present membership above given is full paid and active, and with the effort inaugurated and now in progress, the membership should be built up during the coming year sufficiently to insure the necessary income covering fixed expenses. Each member, in attendance at this Convention is especially urged to assist in securing additional memberships during the Convention.

Certificate of Membership.—A dignified certificate of membership has been prepared by the Executive Committee, and each member of the Association is urged to secure one.

Annual Statement of the Treasurer.

RECEIPTS.

Balance, January 1, 1909		$3,238 23
Dues	$2,630 00	
Dues, Contributing Members	650 00	
Publication, Sales and Advertising	1,614 50	
Exhibition, Cleveland	3,613 90	
Interest on Deposits	15 84	
Miscellaneous	14 51	
Total Receipts		8,538 75
		$11,776 98

EXPENDITURES.

Salaries	$2,115 00		
Office Rent	300 00		
Postage, Printing, Stationery, etc.	751 36		
Office Equipment	35 95		
Meetings Executive Board	180 46		
Committees	156 74		
Publications	633 02		
Convention, Cleveland	1,442 89		
Exhibition, Cleveland	4,767 28		
Premium on Bonds	75 00		
Audit of Accounts	25 00		
Miscellaneous	5 94		
Total Expenditures		$10,488 64	
Balance, December 31, 1909		1,288 34	
			$11,776 98

Due John C. Winston Company for bills incurred and unpaid during year 1909, printing proceedings, etc., $3,688.79.

PHILADELPHIA, 26th May, 1910.

We hereby certify that we have audited the accounts of the Treasurer of the National Association of Cement Users for the year ended 31st December, 1909, and found that the dues collected and receipts from sales of publications, etc., as set forth in the cash book had been properly accounted for, and that all disbursements were substantiated by vouchers.

The foregoing report of the Treasurer is in agreement with the books of account.

(Signed) LYBRAND, ROSS BROS. AND MONTGOMERY,
Certified Public Accountants.

Proceedings.—The volume last issued is superior to anything yet attempted by this Association, and we believe is superior, in some respects, to the proceedings issued by some of the older and more technical bodies; in this the Association may take a just pride. This has not been accomplished without additional expense, however, and the Executive Board feel that this expense should be reduced until the financial affairs of the Association will warrant it, but it must be taken into account that the size of the volume is increasing with each annual convention, and judging from the papers to be presented at this meeting, and the full discussion following, it is not reasonable to expect that any reduction in size can be effected.

The value of our Proceedings cannot but impress the members of this Association, and is further evidenced by the fact that technical and other libraries have, during the past year, secured complete sets of our previous Proceedings and will continue to take same, during the life of this organization.

Standard Specifications.—Members are urged to adopt and promulgate the standards fixed by the Association, and by so doing add to their own reputation and bring about a greater confidence in all forms of concrete work, which of necessity would result to the immediate advantage of the members of this Association.

Convention.—Serious consideration was given by the Executive Board to the place of holding the present Convention, and the educational advantage of holding our meetings in different sections of the country was not overlooked, but with the exhibit feature added and the fact that our exhibitors have never yet been fully satisfied in the matter of allowable space, our selection of a Convention place was considerably narrowed, and in order that many of our exhibitors could this year be saved the expense of a double exhibit, it was finally decided to hold a joint exhibition in conjunction with the Cement Products Exhibition Company, and in doing so, satisfactory financial arrangements were effected. It was also deemed expedient to hold the Convention this year in the Middle West, owing to the fact that the two previous were held in the Central East.

Amendments to By-Laws.—It is recommended that the close of the fiscal year be made June 30th, for the reason that it has

been very difficult in the past to separate the year's expenses, owing to the overlapping of accounts covering the Convention. By changing the date to June 30th, a much better analysis can be made of the finances of the Association.

Headquarters.—With the great amount of detail and clerical work incident to the editing of proceedings, issuance of bulletins and other routine, the necessity of permanent headquarters has been further emphasized, and the Board feels justified in having established same. The expense incident to this, however, has been considerable, and cannot be expected to show a decrease, but rather an increase. But when the necessity of headquarters and a regular paid assistant was first considered, your Board undertook this expense at the request of the Convention, on the promise that a sufficient number of contributing members would be secured to yield the Association an annual income of at least $2,500, but we regret to report that the attempt to secure the support of this contributing membership has thus far failed to produce expected results, and we feel that the interests which we fully expected to assist the Association in this, failed to appreciate the educational advantage of the Association, and the material benefit resulting to this class of expected contributors, in the information contributed and to improved standards of work.

Income.—In order to insure the success and permanency of this Association, it is believed that the necessary income should be derived from membership dues alone, and considering the great and growing interests concerned, and the breadth and scope of work possible for this Association to accomplish, it should be an easy matter, if each member of the Association felt a personal responsibility to the extent of actively soliciting ten new members in his locality through personal appeal and letters of explanation of the advantages derived in membership. Only by this united effort and common interest can the desired result be obtained. We do not believe that the expense of the Association can be reduced without materially impairing its usefulness. In fact, only by rigid economy and personal sacrifice on the part of the officers of your Association, has it been possible to keep the expense down to the amounts indicated in the Treasurer's report this last year.

Our President.—In conclusion, your Executive Board are again glad to record their appreciation of the unselfish effort and generous allowance of time given by your President, Mr. Richard L. Humphrey, to the Association. It must be recognized that the preparations for Convention, including the securing of papers and the details involved in the exhibition, have been largely intrusted to the President and has required a great deal of his time which has been freely given, and it would be a great relief to the Directing Head of this organization if the worry and care of meeting necessary fixed expenses could be removed.

The Association is also indebted to its President for the care with which the proceedings have been edited and published. It must be recognized that this added responsibility has been met by your President by considerable personal sacrifice of time and strength, but with the growing experience of a regular Assistant, it is hoped that the President of this Association may be spared much of this work in the future.

Respectfully submitted on behalf of the Executive Board.

W. P. ANDERSON,
E. S. LARNED,
R. P. MILLER,
Committee to Prepare Annual Report.

MINUTES OF MEETINGS OF THE EXECUTIVE BOARD.

BOARD MEETING HELD MARCH 12, 1909, HOUSE OF THE AMERICAN SOCIETY CIVIL ENGINEERS, NEW YORK, N. Y.

Present: Richard L. Humphrey, President; Merrill Watson, M. S. Daniels, E. S. Larned, W. P. Anderson, R. P. Miller, L. V. Thayer and L. C. Wason, Vice-Presidents; George C. Wright, Secretary.

The minutes of the meetings held on January 11th and 14th were approved as read.

On motion, Mr. George C. Wright was elected Secretary, and Mr. H. C. Turner, Treasurer, for the year 1909.

The First and Second Vice-Presidents were elected members of the Executive Committee for the year 1909.

The statement of the accounts of the Cleveland Convention and Exhibition was read, and Mr. M. S. Daniels appointed to audit the accounts.

The President presented designs and bids for a membership certificate, and a committee consisting of the President, R. P. Miller and L. C. Wason was appointed, with power to decide the design and cost.

The time and place of the next Convention was discussed and referred to a committee consisting of the President, Merrill Watson, M. S. Daniels, and H. C. Turner.

The President reported that he had sent the Assistant to the President to the Third Annual Cement Show, to represent the interests of the Association, and his action in the matter was approved.

It was decided to designate the various Standard Specifications, etc., adopted by the Association as "Standards," and to number them consecutively.

On motion, it was decided that in view of the continued illness of the Treasurer, the Assistant to the President be authorized

to deposit funds of the Association to the amount of $1,000 in a Philadelphia bank to be drawn upon by him through check, countersigned by the President.

On the withdrawal of the President, Mr. Daniels read the resolution adopted by the Cleveland Convention in the matter of reimbursing the President for his traveling expenses connected with the work of the Association. On motion, it was decided that an amount be appropriated to fully reimburse the President for his actual traveling, incidental and other expenses incurred on behalf of the Association up to the close of the Convention of 1909, this reimbursement to be made on voucher stating such expenses.

It was decided that the edition of the Proceedings of the Cleveland Convention be 3,000 copies, and that they be electrotyped.

It was the sense of the Board that no further action be taken at this time in the matter of forming local associations.

The question of advertising the work of the Association was discussed, and it was moved that in view of the fact that the Association has a Committee on Publicity, all matters of advertising should be referred to it.

The President was instructed to appoint committees in the various cities for the purpose of increasing the membership of the Association.

Adjournment.

EXECUTIVE COMMITTEE MEETING HELD JUNE 25, 1909, BRUNSWICK BUILDING, NEW YORK, N. Y.

Present: Richard L. Humphrey, President; Merrill Watson and M. S. Daniels, members of the Executive Committee.

A proposition from the Cement Products Exhibition Company, inviting the Association to hold their Sixth Annual Convention in February at Chicago, and a joint cement show was discussed. The President was authorized to negotiate final arrangements.

Adjournment.

EXECUTIVE COMMITTEE MEETING HELD DECEMBER 29, 1909, NEW YORK, N. Y.

Present: Richard L. Humphrey, President; Merrill Watson, M. S. Daniels and H. C. Turner, members of the Executive Committee.

Consideration was given to the details of the approaching Convention and the following action was taken:

The form of program was approved.

The form of badge was approved and details referred to the President.

The following amendment to the By-Laws was approved:

Article I. Strike out old Section 5 and replace by Section 5 (new). Resignation from membership must be presented in writing to the Secretary. Such resignation shall be acceptable only if the dues for the current year are paid and said resignation is received before February of that year.

A daily registration list to be published as follows: Wednesday morning, covering registration up to Tuesday and such subsequent issues as may be deemed necessary.

The President was authorized to take out membership in the National Fire Protection Association.

It was decided to address the various technical societies suggesting membership in this Association.

In view of the uncertainty regarding the collection of unpaid dues for the year 1908, it was decided that such members who are in arrears for the years 1908 and 1909, be advised that upon receipt of $10 they would be credited with dues for 1909 and 1910, and would receive a free copy of Volume IV.

The price of a one-quarter page advertisement in the Proceedings was fixed at $15, and professional cards at $10 per one-eighth page.

The price of the volumes was fixed as follows, to take effect February 1, 1910:

	Non-members.	Members.
Volume I	$3.00	$2.00
Volumes II-V, each...........	5.00	3.00

Libraries and dealers to receive 20 per cent. discount.

Adjournment.

BOARD MEETING HELD JANUARY 18, 1910, NEW YORK, N. Y.

Present: Richard L. Humphrey, President; M. S. Daniels, E. S. Larned, A. E. Lindau, R. P. Miller, F. A. Norris and L. C. Wason, Vice-Presidents; George C. Wright, Secretary, and H. C. Turner, Treasurer.

The minutes of the meetings of the Executive Committee, held June 25 and December 29, 1909, were read and approved.

The Treasurer presented a financial statement. Discussion as to matter of increasing the income of the Association.

It was decided that papers to be presented before the Convention be distributed only after presentation, and the matter of charging for the same be left to the discretion of the President.

The President was authorized to instruct authors of papers not to distribute papers previous to their presentation before the Convention.

It was decided that the badge of last year be continued practically as before and a guest badge be prepared, details to be left to the President.

The action of employing Lybrand, Ross Brothers and Montgomery of Philadelphia to audit the accounts of the Treasurer for the year ending December 31, 1908, was approved.

It was decided that the same auditing company be employed to audit the accounts of the Treasurer for the year ending December 31, 1909, and copies be sent to the members of the Board.

Adjournment.

PROPOSED REVISION OF BY-LAWS APPROVED BY THE EXECUTIVE BOARD BY LETTER BALLOT, JANUARY 25, 1910.

Amend Article I by striking out Section 5 and inserting a new Section 5 to read as follows:

SEC. 5. Resignation from membership must be presented in writing to the Secretary within thirty days after the close of the fiscal year and shall be acceptable provided the dues are paid for that year.

Strike out Article II and insert a new Article II, as follows:

SECTION 1. The officers shall be the President, the Vice-Presidents, the Secretary and the Treasurer, who, together with the five latest living

Past-Presidents, shall constitute the Executive Board. Vacancies occurring during the year shall be filled by the Executive Board.

SEC. 2. The elective members of the Executive Board, consisting of the President, the First, the Second, the Third and Fourth Vice-Presidents, shall be elected annually by ballot at the convention at a business session fixed by the Executive Board and shall hold office until their successors shall qualify.

SEC. 3. The elective members of the Executive Board shall appoint the Secretary and the Treasurer; they shall create such special committees as may be deemed desirable for the purpose of preparing recommended standards concerning the proper use of cement for consideration by the Association, and shall appoint a chairman for each committee, who shall be a Vice-President of the Association. Four additional members on each special committee shall be appointed by the President, in consultation with the Chairman.

SEC. 4. It shall be the duty of the Executive Board to audit the accounts of the Secretary and the Treasurer before each annual convention.

SEC. 5. The Executive Board shall appoint a Committee on Nomination of Officers and a Committee on Resolutions, to be announced by the President at the first regular session of the annual convention.

SEC. 6. There shall be an Executive Committee of the Executive Board, consisting of the President, the Secretary, the Treasurer and two of its members, appointed by the Executive Board.

SEC. 7. The Executive Committee shall manage the affairs of the Association during the interim between the meetings of the Executive Board.

SEC. 8. The President shall have general supervision of the affairs of the Association. He shall preside at the annual convention, at the meetings of the Executive Board and the Executive Committee, and shall be ex-officio member of all committees.

The Vice-Presidents in order of seniority shall discharge the duties of the President in his absence.

SEC. 9. The Secretary shall perform such duties and furnish such bond as may be determined by the Executive Board.

SEC. 10. The Treasurer shall be the custodian of the funds of the Association and shall disburse the same in the manner prescribed by the Executive Board. He shall furnish bond in such sum as the Executive Board may determine.

SEC. 11. The Secretary and the Treasurer shall receive such salaries as may be fixed by the Executive Board.

Amend Article III to read as follows:

SECTION 1. The Association shall meet annually. The time and place shall be fixed by the Executive Board, and notice of this action shall be mailed to all members at least thirty days previous to the date of the Convention.

SEC. 2. The Executive Board shall meet during the Convention at which it was elected, effect organization, and transact such business as may be necessary.

SEC. 3. The Executive Board shall meet at least twice each year. The time and place to be fixed by the Executive Committee.

Amend Article IV to read as follows:

SECTION 1. The fiscal year shall commence on the first of January* and all dues shall be payable in advance.

SEC. 2. The annual dues of each member shall be five ($5.00) dollars.

SEC. 3. A member whose dues remain unpaid for a period of one year shall forfeit the privilege of membership and shall be officially notified to this effect by the Secretary, and if these dues are not paid within thirty days thereafter his name shall be stricken from the list of members. Members may be reinstated upon the payment of all charges upon the books of the Association.

Amend Article VI to read as follows:

SECTION 1. Amendments to these By-Laws, signed by at least three members, must be presented in writing to the Executive Board prior to November 1st, and shall be printed in the notice of the annual convention. These amendments may be discussed and amended at the annual convention and passed to letter ballot by a two-thirds vote of those present. Two-thirds of the votes cast by letter ballot shall be necessary for their adoption.

BOARD MEETINGS HELD FEBRUARY 21-24, 1910, AUDITORIUM HOTEL, CHICAGO, ILL.

Present: Richard L. Humphrey, President; E. S. Larned, George C. Walters, W. P. Anderson, C. W. Boynton, W. H. Ham, A. E. Lindau, R. P. Miller, L. V. Thayer and L. C. Wason, Vice-Presidents; George C. Wright, Secretary; H. C. Turner, Treasurer.

Minutes of the meetings of the Board of March 12, 1909, and January 18, 1910, were approved as read.

The Treasurer presented his annual report.

A committee consisting of the Treasurer, A. E. Lindau and L. C. Wason, was appointed to go over the receipts and expenditures for the year 1909 with a view of determining how the ex-

*Article IV Section 1, was amended by the Convention so that the fiscal year shall commence on July 1st.—ED.

penses can be reduced for the coming year and also to find new sources of revenue.

A committee consisting of A. E. Lindau and L. C. Wason was appointed to audit the accounts of the Secretary and the Treasurer.

In view of the proposed amendments to the By-Laws, it was the sense of the Executive Board that the Nominating Committee be instructed to present the names of candidates for the offices of President, First, Second, Third and Fourth Vice-Presidents only.

The following committees were appointed:

Committee on Nomination of Officers:

P. Austin Tomes (Chairman), New York, N. Y.
H. S. Doyle, Chicago, Ill.
P. S. Hudson, Louisville, Ky.
A. J. Maynard, State Farm, Mass.
H. H. Rice, Denver, Colo.

Committee on Resolutions:

Ernest McCullough (Chairman), Chicago, Ill.
A. C. Birnie, Ludlow, Mass.
Edward M. Hagar, Chicago, Ill.
O. U. Miracle, Minneapolis, Minn.
Emile G. Perrot, Philadelphia, Pa.
Ira A. Williams, Ames, Iowa.

A committee consisting of W. P. Anderson, E. S. Larned, R. P. Miller, was appointed to prepare the report of the Executive Board.

The Auditing Committee, consisting of A. E. Landau and L. C. Wason, presented a report recommending the appointment of two committees, one to look into the best method of increasing the revenue of the Association. The committee also recommended that the Proceedings of the Chicago Convention be edited, but not printed until this committee reports.

W. H. Ham, E. S. Larned and A. E. Lindau were appointed a committee to consider and report ways and means of increasing the membership and revenue of the Association.

The annual report of the Executive Board, presented by the committee consisting of W. P. Anderson, E. S. Larned and R. P. Miller, was read and approved.

It was decided to designate the following sectional committees for the coming year:

Building Blocks and Cement Products.
Exhibition.
Fireproofing.
Insurance.
Reinforced Concrete and Building Laws.
Roadways, Sidewalks and Floors.
Treatment of Concrete Surfaces.

Adjournment.

MEETING OF ELECTIVE MEMBERS OF THE EXECUTIVE BOARD HELD FEBRUARY 25, 1910, AUDITORIUM HOTEL, CHICAGO, ILL.

Present: Richard L. Humphrey, President; Edward D. Boyer and E. S. Larned, Vice-Presidents.

The following officers were elected for the year 1910:

Vice-Presidents being Chairman of the Sections named.

Building Blocks and Cement Products, W. P. Anderson.
Exhibition, H. S. Doyle.
Fireproofing, Rudolph P. Miller.
Insurance, William H. Ham.
Reinforced Concrete and Building Laws, Alfred E. Lindau.
Roadways, Sidewalks and Floors, C. W. Boynton.
Treatment of Concrete Surfaces, Leonard C. Wason.

Treasurer:
Henry C. Turner.

Adjournment.

REGISTER OF ATTENDANCE.
SIXTH CONVENTION.

Richard L. Humphrey, Philadelphia, Pa.
Edward D. Boyer, Catasauqua, Pa.
M. S. Daniels, Suffern, N. Y.
E. S. Larned, Boston, Mass.
George C. Walters, Atlanta, Ga.
George C. Wright, Rochester, N. Y.
H. C. Turner, New York, N. Y.
W. P. Anderson, Cincinnati, Ohio.
C. W. Boynton, Chicago, Ill.
H. S. Doyle, Chicago, Ill.
William H. Ham, Boston, Mass.
P. S. Hudson, Louisville, Ky.
Alfred E. Lindau, St. Louis, Mo.
Rudolph P. Miller, New York, N. Y.
L. V. Thayer, Minneapolis, Minn.
Leonard C. Wason, Boston, Mass.
Edward E. Krauss, Philadelphia, Pa.

Abbey-Dodge-Brooks Concrete Company, The. Raymond E. Brooks, Newark, N. J.
Aberthaw Construction Company. Leonard C. Wason, Boston, Mass.
Abrams, Duff Andrew, Urbana, Ill.
Adams, Adolph, Kendallville, Ind.
Adkins, H. L., Jonesboro, Arkansas.
Affleck, B. F., Chicago, Ill.
Aiton, J. L., Alexandria, Minn.
Allen, Herbert B., Louisville, Ky.
Allen, Orrin T., Chicago, Ill.
Alpha Portland Cement Company, Easton, Pa.
American Hydraulic Stone Company. Harmon H. Rice, Denver, Col.

American Steel and Wire Company. H. S. Doyle, Chicago, Ill.
Anderson, A. O., Lake City, Iowa.
Anderson, Robert, Cincinnati, Ohio.
Appleton Sewer Pipe Works. M. K. Gochnauer, Appleton, Wis.
Armstrong Cement Works. P. H. Atwood, Armstrong, Iowa.
Ash Grove Lime and Portland Cement Company. W. B. Phillips, Kansas City, Mo.
Ashland Steel Range and Manufacturing Company. U. S. Shelly, Ashland, Ohio.
Auerbach, Henry, Brooklyn, N. Y.
Ball Brothers. F. L. Ball, Twin Falls, Idaho.
Ballinger, Walter F., Philadelphia, Pa.
Ballou Manufacturing Company. W. D. Ballou, Belding, Mich.
Balyeat, R. M., Van West, Ohio.
Barnes, Arthur, Pittsburgh, Pa.
Barry, E. J., Jersey City, N. J.
Bartlett, G. S., Chicago, Ill.
Bartlett Lumber Company, The. J. L. Bartlett, Greeley, Col.
Battjes, F., Grand Rapids, Mich.
Battjes Fuel and Building Material Company. N. H. Battjes, Grand Rapids, Mich.
Baumberger, John R., Kokomo, Ind.
Beck, J. P., Chicago, Ill.
Bell, H., Ware, Mass.
Besser Manufacturing Company, The. J. H. Besser, Alpena, Mich.
Beyer, Ira, Mishicot, Wis.
Binswanger, S. J., Chicago, Ill.
Bird, C. H., New Haven, Conn.
Birnie Company, Alexander C. A. C. Birnie, Ludlow, Mass.
Black, Joseph A., Hoopeston, Ill.
Blanc Stainless Cement Company. J. Maxwell Carrere, Allentown, Pa.
Blethyn, Benjamin, Washington, D. C.
Blystone, Perry L., Cambridge Springs, Pa.
Bordner and Parker. Amos Bordner, Clinton, Ill.
Bovee and Son, M., Northville, Mich.
Brainerd, E. LeRoy, Hoboken, N. J.

Brannin, Addison, Aberdeen, Miss.
Briggs, James E., Waterloo, Iowa.
Brown Hoisting Machinery Company. George T. Sinks, Cleveland, Ohio.
Bruck, A. J., Peru, Ind.
Buser Concrete Construction Company. N. E. Buser, Mount Morris, Ill.
Bush, R. G., Plainfield, N. J.
Butler Wood Fiber Plaster Company, The. S. C. Kelly, Butler, Pa.
Cadwell Silex Stone Company, The. C. W. Cadwell, West Windsor, Canada.
Campbell, James C., Chicago, Ill.
Carey Concrete Company. W. H. Carey, Grand Rapids, Wis.
Carlon Construction Company. George H. Carlon, Oskaloosa, Iowa.
Cement. R. B. Sears, New York, N. Y.
Cement Age. A. M. Ferry, Philadelphia, Pa.
Cement and Engineering News. William Seafert, Chicago, Ill.
Cement Era. E. S. Hanson, Chicago, Ill.
Cement Stone and Supply Company. I. F. West, Wichita, Kan.
Central Concrete Construction Company. P. S. Hudson, Louisville, Ky.
Central Construction Company, The. I. A. Andrew, Wooster, Ohio.
Chain Belt Company. John M. Trevor, Milwaukee, Wis.
Chandler, Dana G., Sylvania, Ohio.
Chapleau, S. Jefferson, Ottawa, Canada.
Chapman, Incorporated, C. A. C. A. Chapman, Chicago, Ill.
Charles, Fred R., Richmond, Ind.
Chase Foundry and Manufacturing Company. S. M. Chase, Columbus, Ohio.
Chicago Portland Cement Company. J. U. C. McDaniel, Chicago, Ill.
Clark, Frank E., Bridgeport, Conn.
Clinton Wire Cloth Company. J. W. Stromberg, New York, N. Y.
Clyde, William G., Pittsburgh, Pa.

Cohen, A. B., East Orange, N. J.
Colby, C. C., Lawrence, Mass.
Colby, Charles H., Des Moines, Iowa.
Collier, D. M., Albany, N. Y.
Collins and Company, W. A. W. A. Collins, Chicago, Ill.
Commonwealth Construction Company, The. Fred C. Dreher, Denver, Colo.
Compton, L. L., Wilmington, Ohio.
Concrete. Walter C. Boynton, Detroit, Mich.
Concrete Age, The. George C. Walters, Atlanta, Ga.
Concrete Engineering. Allen Brett, Cleveland, Ohio.
Concrete Stone and Sand Company, The. A. A. Pauly, Youngstown, Ohio.
Concrete Stone Company. H. L. Green, Waterloo, Iowa.
Connell, C. H., Youngstown, Ohio.
Connelly, P. F., Elreno, Okla.
Converse and Company, H. P., Boston, Mass.
Cook, A. B., Petersburg, Va.
Corn Palace Cement Works. P. P. Comoli, Sioux City, Iowa.
Corrugated Bar Company. P. D. Gilhan, St. Louis, Mo.
Corrugated Bar Company. W. S. Thomson, Chicago, Ill.
Crawford, Wesley L., Highwood, Conn.
Cromar, A. J., Brantford, Canada.
Crowell, E. H., Crown Point, Ind.
Crozier, Alfred O., Wilmington, Del.
Cummings Structural Concrete Company. Robert A. Cummings, Pittsburgh, Pa.
Cunard-Lang Concrete Company, The. A. C. Uhle, Columbus, Ohio.
D. and A. Post Mold Company, The. G. H. Dougherty, Three Rivers, Mich.
Davis, Benjamin Herman, New York, N. Y.
Davy, Harold M., Ottawa, Canada.
De Pay, W. B., Kalamazoo, Mich.
De Smet, George W., Chicago, Ill.
Detroit Fireproofing Tile Company. A. C. Raymond, Detroit, Mich.
Dexter Portland Cement Company. Nazareth, Pa.

Dietrichs Clamp Company. Charles Dietrichs, Little Ferry, N. J.
Dings, L. E., Sylvania, Ohio.
Dresch, Martin, Pierron, Ill.
Drum and Company, A. L. A. L. Drum, Chicago, Ill.
Duboyce, William J., Philadelphia, Pa.
Dyer, Wesley E., Muskegon, Mich.
Ed, Robert, Moline, Ill.
Edelman, John, Muskegon, Mich.
Edison Portland Cement Company, The. Stewartsville, N. J.
Eilbacher, Joseph F., Elizabeth, N. J.
Ellendt, John G., Rochester, N. Y.
Elyria Lumber and Coal Company, The. H. B. Hecock, Elyria, Ohio.
Engineering Record. E. J. Mehren, New York, N. Y.
Eureka Machine Company. O. S. Case, Lansing, Mich.
Ewing Concrete Company, The Davis. Davis Ewing, Bloomington, Ill.
Fechheimer, S. M., Detroit, Mich.
Ferro-Concrete Construction Company, The. W. P. Anderson, Cincinnati, Ohio.
Figgie, H. E., Cleveland, Ohio.
Filson, Charles M., Xenia, Ill.
Fisher Hydraulic Stone and Machinery Company. W. H. Fisher, Mt. Gilead, Ohio.
French and Company, Samuel H. Raymond W. Hilles, Philadelphia, Pa.
Fulton, Harry P., Marshall, Minn.
Garden City Sand Company. C. B. Shefler, Chicago, Ill.
Genther, William J., East Rochester, N. Y.
Gibson, R. A., Hot Springs, Ark.
Gilbreth, Incorporated, Frank B. Frank B. Gilbreth, New York, N. Y.
Gill, J. Robert., Chicago, Ill.
Gillespie, Peter, Toronto, Canada.
Godfrey, Joseph V., Moorhead, Minn.
Goodman-McCormick. Des Moines, Iowa.
Good Roads Magazine. E. L. Powers, New York, N. Y.
Gould and Son, O. C. F. D. Gould, Fairmount, Minn.

Green, Theodore, Chicago, Ill.
Greenman, R. S., Albany, N. Y.
Guay, T. J., Laconia, N. H.
Hall, Albert Acton, Piqua, Ohio.
Hamann, C. H., Geneseo, Ill.
Hamlin, F. M., Lake Villa, Ill.
Hanna, William P., New Castle, Pa.
Hastings, C. B., Brookville, Pa.
Hatch, Leonard C., Piqua, Ohio.
Havlik, Robert F., South Bend, Ind.
Healy, Clarence, Hoboken, N. J.
Hocking Valley Railway. J. S. Eastman, Columbus, Ohio.
Hoff, Charles A., Lykens, Pa.
Hopper, James G., Ridgewood, N. J.
Horn Company, A. C., New York, N. Y.
Hot Springs Concrete Company. C. E. Marks, Hot Springs, Ark.
Howe, H. N., Memphis, Tenn.
Hugo and Company. O. K. Hugo, Whitewater, Wis.
Humphreys, P. J., East Liberty, Ohio.
Ideal Concrete Machinery Company. Mentor Wetzstein, South Bend, Ind.
Ingle, A. H., Rochester, N. Y.
Insurance Engineering. G. H. Stewart, New York, N. Y.
Iowa Association of Cement Users. George H. Carlon, Oskaloosa, Iowa.
Irvine, Fred K., Chicago, Ill.
Jaeger Automatic Machine Company, Columbus, Ohio.
Jeannette Concrete Construction Company. S. F. Boyer, Jeannette, Pa.
Jeffer and Christopher. Joseph H. Christopher, Ridgewood, N. J.
Kearney, J. W., New Orleans, La.
Kelley, Charles B., Wichita, Kansas.
Kenney and Sons, E. Lloyd W. Kenney, Creston, Iowa.
Kent Machine Company, The. F. A. Kershaw, Kent, Ohio.
Kerlin Automatic Post Machine Company. W. F. Kerlin, Delphi, Ind.
Kerr, H. R., Cleveland, Ohio.
Ketchin and Son, A. J. W. M. Ketchin, Tariffville, Conn.

Kilgus, Fred, Newark, N. J.
Kimball, C. A., New York, N. Y.
Kinney, William M., Pittsburgh, Pa.
Kleiderer and Son, C. F., Henderson, Ky.
Knapp and Company, C. R. C. R. Knapp, Philadelphia, Pa.
Knickerbocker Company, The. W. B. Knickerbocker, Jackson, Mich.
Knightstown Concrete Company. W. S. Garritson, Knightstown, Ind.
Kramer Automatic Tamper Company. W. H. Janssen, Peoria, Ill.
Kranz and Wehaner. Henry J. Kranz, Harbor Beach, Mich.
Kuhnen, Louis O., Highland, Ill.
Lambarton Cement Block and Tile Company. Charles Newdall, Lambarton, Minn.
Land, Marion O., St. Joseph, Mo.
Lauer, Walter F., Webster, N. Y.
Lauer and Sons Company, F. C. George W. Lauer, South Rochester, N. Y.
Laughlin, A. H., Lisbon, N. D.
Lawrence Cement Company of Pennsylvania, The. E. F. Sheppard, Plainfield, N. J.
Ledlie, David B., Saratoga Springs, N. Y.
Lee, Walker S., Rochester, N. Y.
Leland, Ira S., Milwaukee, Wis.
Lensing, H. A., Evansville, Ind.
Lincoln Stone and Supply Company. C. R. Lehrack, Lincoln, Neb.
Lindsley Company, The C. E. C. E. Lindsley, Irvington, N. J.
Lippold, B. F., Chicago, Ill.
Lloyd, Harry A., Jersey City, N. J.
Lykens Concrete Block Manufacturing Company. Charles A. Hoff, Lykens, Pa.
MacMillan, Angus B., Brookline, Mass.
Maine, H. A., Des Moines, Iowa.
Manufacturers' Record. William H. Stone, Baltimore, Md.
Marvick, Martin O., Story City, Iowa.
Maynard, Arthur J., State Farm, Mass.

McAvoy, J. E., White Hall, Ill.
McCarty, Joseph, Kaukauna, Wis.
McCord, H. C., Columbus, Neb.
McCullough, Ernest, Evanston, Ill.
McDaniel, J. U. C., Chicago, Ill.
McDonald, Dudley, Petoskey, Mich.
Meacham and Wright Company. C. M. Foster, Chicago, Ill.
Mensch, L. J., Chicago, Ill.
Merillat Culvert Core Company, Winfield, Iowa.
Miller Company, Incorporated, Charles R. Charles R. Miller, Memphis, Tenn.
Miracle Pressed Stone Company. O. U. Miracle, Minneapolis, Minn.
Morgan, A. W., Grand Rapids, Mich.
Morlan, John H., Fairfield, Ill.
Morrill, Milton Dana, Washington, D. C.
National Roofing Company, The. John Ayrault, Tonawanda, N. Y.
National Wire Cloth Company. George J. Schade, Sandusky, Ohio.
Neel, Lewis M., Hoboken, N. J.
Nelson, George, Madison, Wis.
Newton, W. M., Wyoming, Del.
New Way Motor Company, The. E. W. Goodnow, Lansing, Mich.
New York, City of. Horace Loomis, New York, N. Y.
Nies, F. J., Hoboken, N. J.
Northwestern States Portland Cement Company, Jackson, Mich.
Ogden and Cadmus. E. L. R. Cadmus, Bloomfield, N. J.
Palmer, Howard Van R., New York, N. Y.
Parsons, O. B., Shreve, Ohio.
Patch, William E., Rutland, Vt.
Patton Paint Company. William H. Reese, Milwaukee, Wis.
Pawtucket Granolithic Construction Company, Incorporated. Francis A. Sylvestre, Pawtucket, R. I.
Pease, Bernard S., Chicago, Ill.
Peerless Brick Company, Incorporated. R. O. Howard, Seattle, Wash.

Peerless Brick Machine Company. L. V. Thayer, Minneapolis, Minn.
Perfect Cement Block Company, The. Emil C. Deinlein, Milwaukee, Wis.
Perrot, Emile G., Philadelphia, Pa.
Peters, Carl, Alloway, N. J.
Phipps, F. S., St. Joseph, Mo.
Pinney, E. E., Liberty, N. Y.
Pittsburgh Steel Products Company. Howard M. Hooker, Pittsburgh, Pa.
Plumb, R. Alfred, Detroit, Mich.
Porter, Harry Franklin, Kansas City, Mo.
Pulfer, George B., South Bend, Ind.
Quinn, Theobald M., Rochester, N. Y.
Rader, B. H., Pittsburgh, Pa.
Reiff, John S., Lykens, Pa.
Richardson, A. E., Saginaw, Mich.
Richmond Concrete Stone Company. W. H. Dunn, Richmond, Va.
Richter, Edwin P., Chicago, Ill.
Rightmyer, Jay S., Auburn, N. Y.
Robinson, A. M., Neponset, Ill.
Roche, Edward, Far Rockaway, N. Y.
Rochester Composite Brick Company. R. W. Holden, Rochester, N. Y.
Rochester Lime Company. J. M. Hamilton, Rochester, N. Y.
Rock Products. E. H. Defebaugh, Chicago, Ill.
Roess, Gustav F., Oil City, Pa.
Romaine, Jr., Henry F., Kingston, Pa.
Rosenberger, Oliver, Lansdale, Pa.
Russell, R. H., Walton, N. Y.
Saal and Brooking. Adam Saal, Pekin, Ill.
Sanders, Francis C., Boise, Idaho.
Sandusky Portland Cement Company. Spencer B. Newberry, Sandusky, Ohio.
Schubert, B., Brooklyn, N. Y.
Schuyler, John P., Medina, N. Y.
Scroggie, James H., Olmsted Falls, Ohio.

Seaman, Henry J., Catasauqua, Pa.
Senft, Jr., George, Ligonier, Pa.
Shankland, Edward Clapp, Chicago, Ill.
Simpson Cement Mold Company, The. H. G. Simpson, Columbus, Ohio.
Smith, George, Jr., Kearney, N. J.
Smith, J. Augustine, South Bend, Ind.
Snodgrass, A. E., Sellersburg, Ind.
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Wolverine Portland Cement Company. E. R. Root, Coldwater, Mich.
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Worm, Fritz, La Salle, Ill.

SUBJECT INDEX.

AUTHOR INDEX.

LIST OF PUBLICATIONS.

A. PROCEEDINGS

VOLUME I.

Coloring of Concrete—J. P. Sherer.
Testing of Cement Blocks—Prof. John R. Allen.
The Dry Mixture of Concrete—A. L. Goetzmann.
Practical Work of Constructing Sidewalks—A. T. Gridley.
The Waterproofing of Concrete Blocks—G. B. Kirwan.
Waterproofing Concrete—W. H. Finley.
Cement Posts—J. A. Mitchell.
Mortar Sand—J. C. Hain.
Proceedings of the Convention.
  Discussion:
    Coloring of Concrete.
    Testing of Cement Blocks.
    The Mixing of Concrete.
    The Practical Work of Constructing Sidewalks.
Registry of the Convention.
List of Exhibitors.

VOLUME II.

Annual Presidential Address—Richard L. Humphrey.
Concrete Aggregates—Sanford E. Thompson.
Discussion on Concrete Aggregates.
Cement and Building Construction—C. A. P. Turner.
Discussion on Cement Construction.
Concrete Building Blocks—S. B. Newberry.
Discussion on Cement Building Blocks.
Some Notes on Reinforced Concrete—A. L. Johnson.
The Use of Cement and Concrete for Farm Purposes—S. M. Woodward
What the Cement Users Owe to the Public—R. W. Lesley.
Cement Block Architecture—Louis H. Gibson.
Waterproofing—J. L. Mothershead, Jr.
The Causes of Failure in the Concrete Block Business—O. U. Miracle.
The Selection of Portland Cement to be Used in the Manufacture of Concrete Blocks—Richard K. Meade.
Legislation Concerning the Use of Cement in New York City, R. P. Miller

Legislation on Concrete Building Blocks—Will J. Scoutt.
Hair Cracks, Crazing or Map Cracks on Concrete Surfaces—Albert Moyer.
Report of Committee on Fireproofing and Insurance—E. T. Cairns.
Report of Committee on Art and Architecture—Charles D. Watson.
Machinery for Cement Users—W. W. Benson.
Topical Discussion on Cement Products.
Observations on the Testing and Use of Portland and Natural Cements—E. S. Larned.
Manufactured Stone—J. C. McClenahan.
The Manufacture and Use of Concrete Piles—Henry Longcope.
The Use of Salt in Concrete Sidewalk Construction—George L. Stanley.
Topical Discussion on Sidewalk Laying.
General Discussion on Cement and Concrete.
Summary of Proceedings.
Registry of Members in Attendance.
List of Exhibitors.
Minutes of the Meetings of the Executive Board.
List of Members.

VOLUME III.

Summary of Proceedings of the Third Convention.
Annual Address by the President—Richard L. Humphrey.
The Successes and Failures of Cement Construction.
Report of Committee on Sidewalks, Streets and Floors—George L Stanley, Chairman.
Discussion on Sidewalk Construction.
Cement Sidewalk Paving—Albert Moyer.
Reinforced Concrete—W. K. Hatt.
Forms for Concrete Construction—Sanford E. Thompson.
Topical Discussion on the Manufacture of Concrete Blocks.
Selecting the Proportions for Concrete—William B. Fuller.
Report of Committee on Testing of Cement and Cement Products—E. S. Larned, Chairman.
Discussion on Steam Curing of Blocks.
The Artistic Treatment of Concrete—A. O. Elzner.
Concrete Surfaces—H. H. Quimby.
Treatment of Concrete Surfaces—Linn White.
Report of Committee on Art and Architecture—Charles D. Watson, Chairman.
Discussion on Streets, Sidewalks and Floors.
Concrete Blocks—Harmon H. Rice.
Discussion on Building Blocks.
Tests of Building Blocks—R. D. Kneale.
Report of Committee on Machinery for Cement Users—J. F. Angell, Chairman.
Topical Discussion on the Manufacture of Cement Blocks.

VOLUME IV.

VOLUME V.

Cost of Concrete Construction as applied to Buildings—Leonard C. Wason.
Discussion.
Comparative Cost of Reinforced Concrete Buildings—Emile G. Perrot.
Monolithic Concrete Wall Buildings—Methods, Construction and Cost—Robert Aiken.
Cold Storage Warehouses of Reinforced Concrete Construction—J. P. H. Perry.
Discussion.
Evolution of Reinforcement for Concrete—Harry F. Porter.
Concrete Applied to Dwelling House Construction—Ross F. Tucker.
Waterproofing—Various Applications and Comparative Costs—T. Hugh Boorman.
Methods of Attaching Shafting and Machinery in Reinforced Concrete Buildings—Wm. M. Bailey.
Report of Committee on Art and Architecture—Albert Moyer, Secretary.
Decorative Concrete Stone—Frederick A. Norris.
Unburnable Homes—Their Artistic and Architectural Possibilities—Benjamin A. Howes.
The Construction and Cost of Small Concrete Houses—C. R. Knapp.
The Importance and Cost of Cement Testing—W. Purves Taylor.
The Availability of Concrete for Bridges—Its Cost and Durability—H. H. Quimby.
Cost of Reinforced Concrete Bridges, Especially with Regard to Maintenance—E. P. Goodrich.
Reinforced Concrete Retaining Walls—A. E. Lindau.
Discussion.
The Applicability and Comparative Cost of Concrete and Reinforced Concrete for Subway Construction—Charles M. Mills.
Discussion.
The Advantages of Reinforced Concrete for Railway Construction—B. H. Davis.
Concrete Piles—Forms, Advantages and Cost as Compared with Wooden Piles—C. W. Gaylord.
Value and Cost of Steel Centers for the Construction of Culverts and Bridges—L. H. Scott.
The Present and Future of the Cement Block—Its Manufacture, Its Availability, Its Cost—J. Augustine Smith.
Value and Cost of Steam Curing of Cement Hollow Blocks—F. S. Phipps.
Progress in the Use of Metal Forms with Comparative Costs—W. L. Caldwell.
Discussion.
Cost and Value of Concrete Pavements—J. H. Chubb.
Report of Committee on Streets, Sidewalks and Floors—W. W. Schouler, Chairman.
Standard Specifications for Portland Cement Sidewalks.
Proposed Specifications for Concrete Roads.

Discussion on Cement Sidewalks.
Discussion on Concrete Roads.
Report of Committee on Insurance, Laws and Ordinances—W. H. Ham, Chairman.
Part I, on Insurance.
Part II, on Building Regulations.
Proposed Standard Building Regulations for Reinforced Concrete.
Discussion on Insurance.
Report of Committee on Reinforced Concrete—Sanford E. Thompson, Chairman.
Discussion.
Report of Committee on Testing Cement and Cement Products—E. S. Larned, Chairman.
Standard Specifications for Cement Hollow Building Blocks.
Discussion on Concrete Blocks.
Topical Discussion on Reinforced Concrete.
Report of the Executive Board.
Minutes of Meetings of the Executive Board.
Register of Attendance—Fifth Convention.
List of Exhibitors—Fifth Exhibition.
List of Members.
Geographical Distribution of Members.
Subject Index.
Author Index.
List of Publications.

VOLUME VI.

For Table of Contents see pp. 3-5.

B. STANDARDS.

1. Standard Specifications for Cement. With Appendix on Standard Methods of Testing and Chemical Analysis.
2. Standard Specifications for Portland Cement Sidewalks.
3. Standard Specifications for Cement Hollow Building Blocks.
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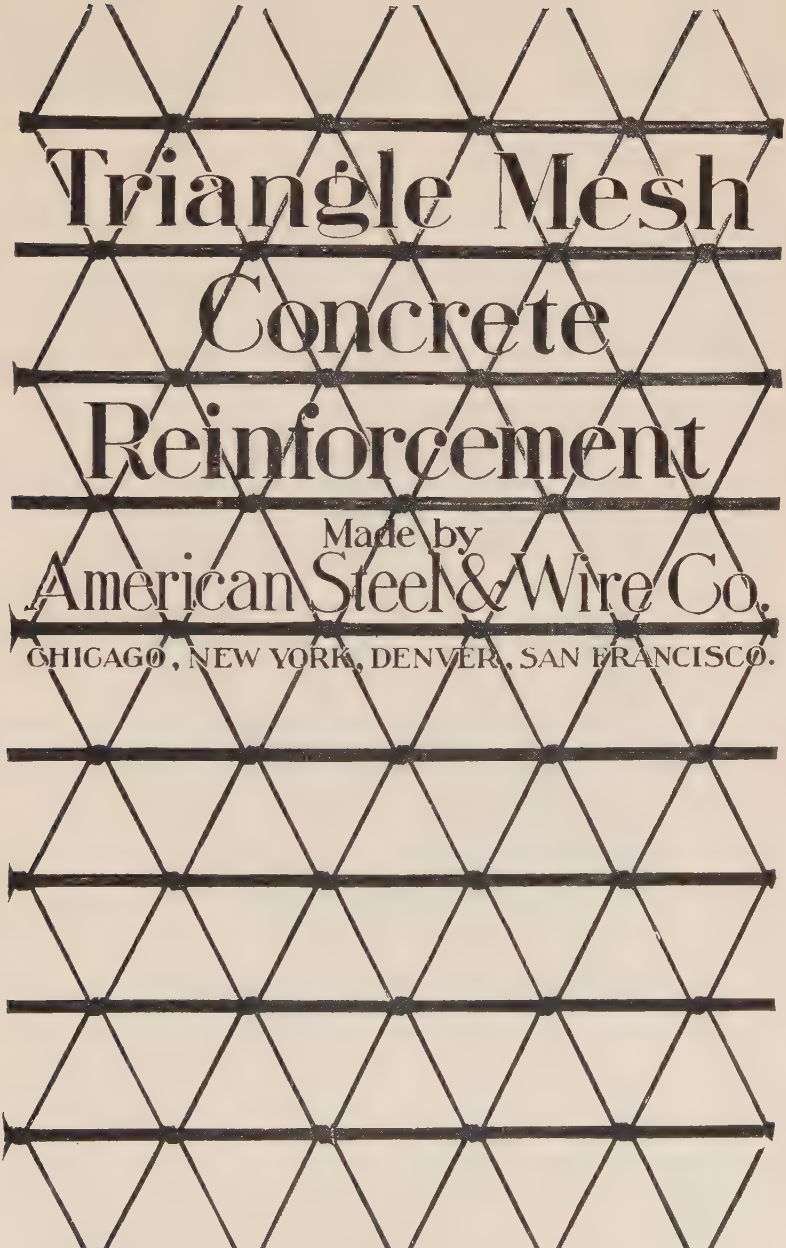
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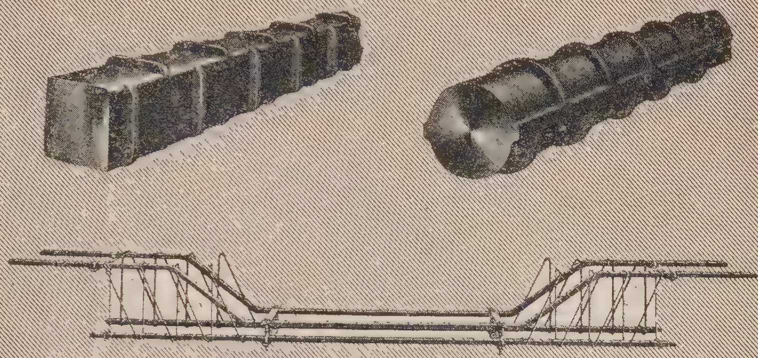

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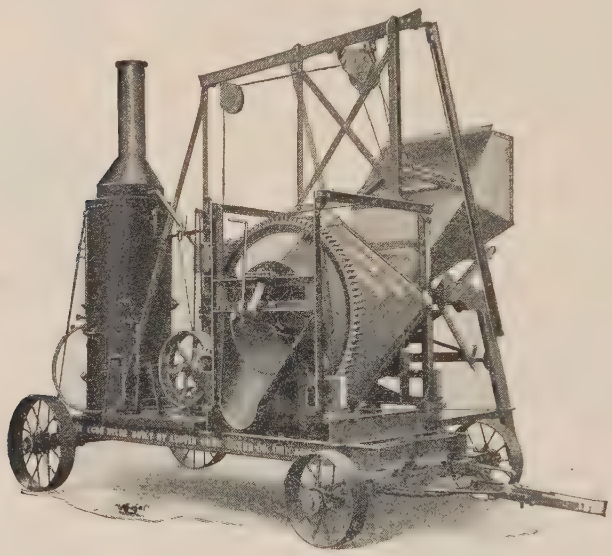

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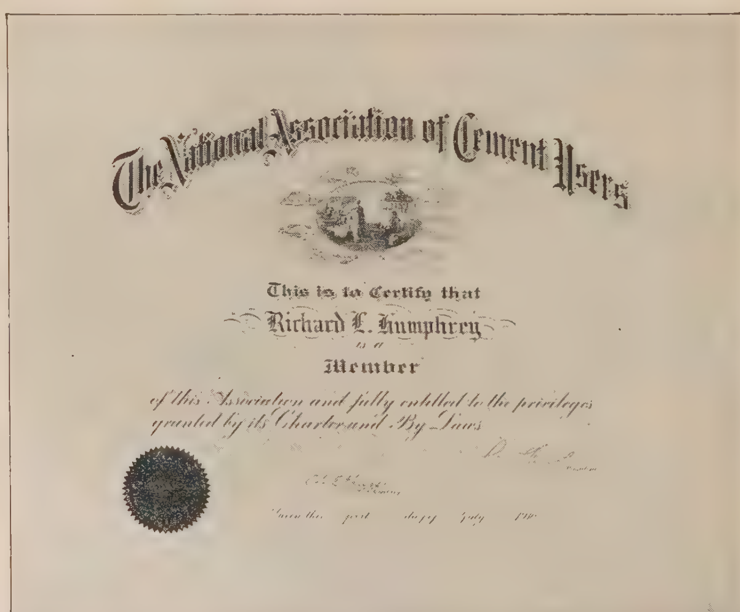
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